Corrosion

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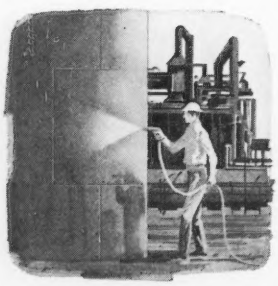

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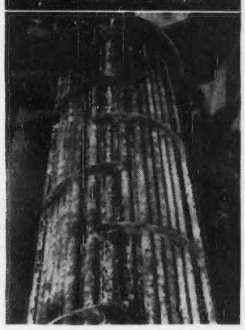

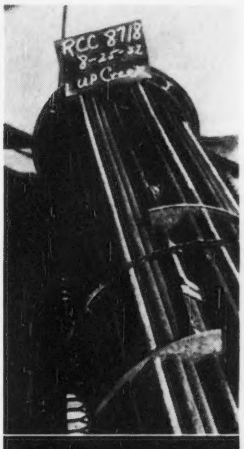

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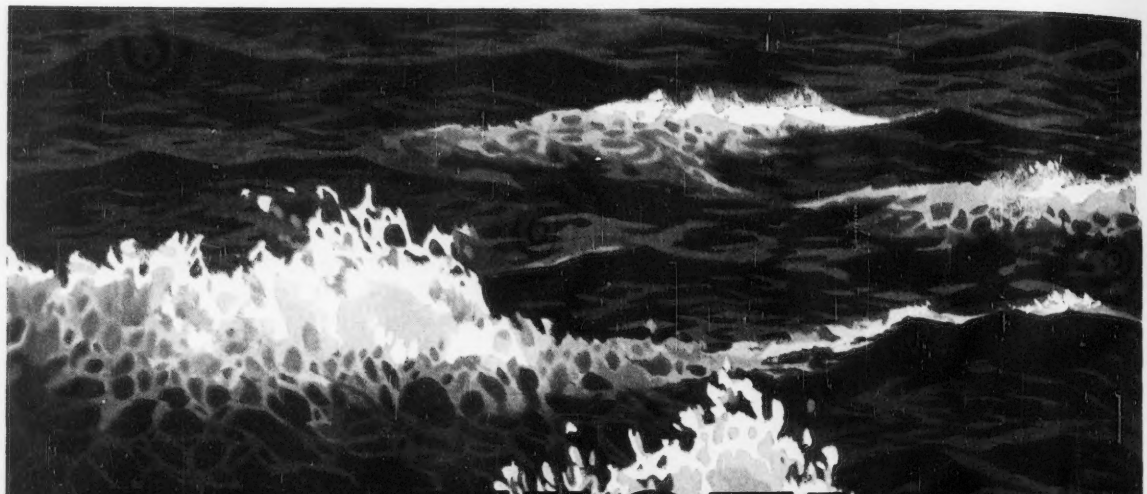

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This Month in Corrosion Control . . .

CAST STEEL IMPELLERS and valves proved more corrosion resistant in a high temperature hot water heating system than brass and bronze pumps and valves in Canada. A thorough report on the solution of this corrosion problem is presented beginning on Page 9.

SOME EXAMPLES of successful use of plastic pipe in corrosive service are given in a short article on Page 14.

HOW CHEMICAL RESISTANT MASONRY is used in numerous corrosion situations is comprehensively covered in an article beginning on Page 18. Considered are the numerous types of bricks, membranes and mortars and construction details that often make the difference between success and failure.

WOODS USEFUL IN CORROSIVE environments and some of the reasons one wood is better than another are explained in an unusually complete article. A table giving nominal resistance of four woods to a list of corrosives is included. See Page 24.

"MINIMUM REQUIREMENTS" mean exactly that, a short discussion of the pipeline corrosion protection position of NACE Technical Committee 2, says on Page 28.

MODULAR PANELIZED buildings which can be quickly erected and quickly taken down for use elsewhere may be a partial answer to the problem of supplying facilities for America's burgeoning school population. Steel frames are erected on a concrete slab, then enclosed with curtain walls made of corrugated, cored aluminum. Roof panels are finished with chlorosulfonated polyethylene. More details on Page 38.

COMPLETE PROGRAMS of two short courses on corrosion control to be held with NACE cooperation this summer may be found in this issue. The course at Ohio State University concerns the process industry (See Page 55) and the one at West Virginia University concerns underground corrosion control (See Page 56).

CURRENT REQUIRED FOR CATHODIC PROTECTION of steel in a high resistivity environment is about three times the magnitude of the corrosion current, NBS researchers reveal in an article beginning on Page 79. Laboratory tests over two months in soil with 20,000 ohms/centimeter showed this.

WHAT HAPPENS AT A STEEL DOCK which is cathodically protected? Is the current applied to structures likely to result in ignition of hydrocarbons? What are the problems and their solutions? Turn to Page 85 for the answers.

ORGANIZATION, FUNCTION and management of a corrosion control organization for a pipeline company are explained by a man who has had lots of experience. Some time and money saving tips on protecting a $375,000,000 investment from corrosion damage are given. Turn to Page 91.

EXPLOSIONS CAN BE AVOIDED in autoclave testing of zirconium alloys with proper precautions. Comparisons are made between corrosion resistance of British and American zirconium alloys on Page 99.

USEFUL PRACTICAL DATA concerning application of impressed current and galvanic anode cathodic protection systems on ship hulls and related parts are summarized in a report by NACE's T-3G-1 Committee on Cathodic Protection of Hull Bottoms of Ships. Turn to Page 103.

SAVINGS FROM IMPROVED rectifiers are described for those concerned with the use of these devices in cathodic protection systems. Advantages of new circuits and control systems are given. See Page 105.

MODELS OF BOILERS designed to operate with energy from nuclear reactors make economical testing of materials possible. Some details of experiments to determine the reaction of various materials are described in an article beginning on Page 111.

HYDROGEN BLISTERING in fluid catalytic cracker components was found to be proportional to an increase in pH in the absorber deethanizer. Other corrosion problems in this type of plant are discussed and some remedies suggested. See Page 116.

HOW COLD WORK affects hydrogen absorption of steel is considered in a description of carefully controlled tests beginning on Page 123.

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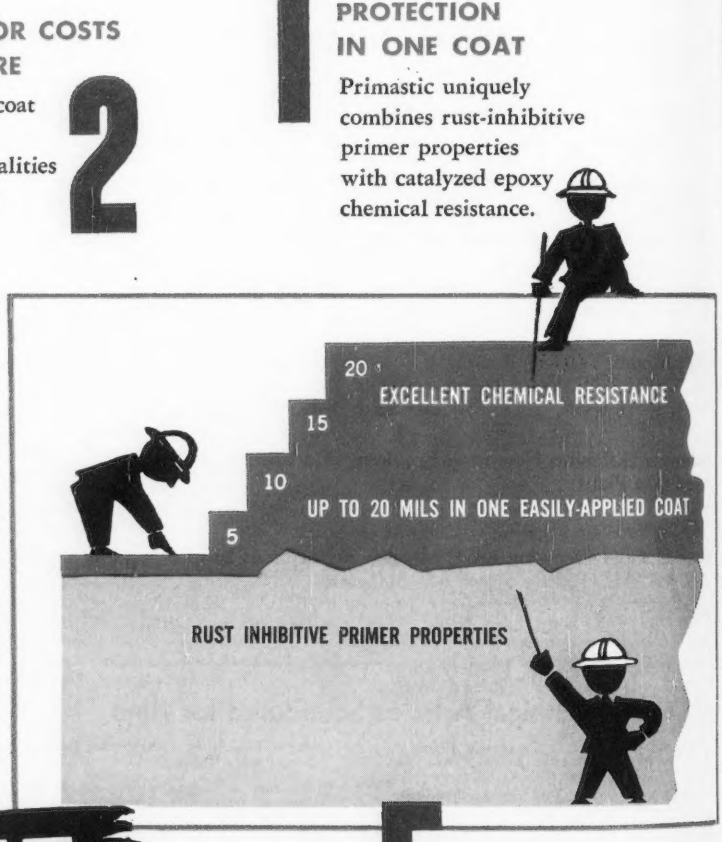

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Why Jump to Conclusions Over a Theoretical Spark?

THE VAST veil of silence that hovers over the loss by explosion of the tanker Stanvac Japan has been penetrated by a few small voices in British corrosion control magazines. The tack taken so far has been defensive, apparently accepting without serious objection the premise that the explosion resulted from some defect in the magnesium anode installation aboard the ship.

Some off-the-record information coming to CORROSION indicates that the belief is held a spark generated when a magnesium anode fell in an empty tank was the cause of the explosion. From what we have been able to learn, it may never be possible to ascertain with any certainty that this actually was, or was not, the cause of the explosion. If this is true, then, the reported hasty removal from tankers of magnesium anode systems may be ill advised, because if the true cause of the disaster was something else, a false sense of security is generated by the removal of the anodes.

Sober reflection casts some doubt that there is significant danger from magnesium anode impact sparks. Admittedly, sparks can be generated by impact between most metals, including magnesium. However, when the mathematical probabilities are weighed of the conditions prerequisite to a magnesium impact spark causing an explosion in an empty oil tank, placing the whole blame on the anodes seems unwarranted.

Consider the conditions necessary: (1) The gas-air mixture would have to be in the narrow range necessary for an explosion. (2) The anode would have to fall far enough to generate sparking energy. (3) The resulting spark would have to be of a magnitude sufficient to ignite the mixture. The likelihood of all these circumstances occurring simultaneously is remote.

On the other hand consider some of the other possible causes of the explosion: (1) Spontaneous combustion in the sludge remaining in the tank bottoms. (2) Spark ignition created by the friction of tank residues moving with the motion of the ship. (3) Ignition heat generated between faying surfaces sliding as result of ship's motion. (4) Galvanic currents discharging between areas of the tank at different solution potentials, temperatures, or conditions of stress. (5) Static generated by condensation of moisture in the tank. Perhaps there are others.

In any case, to discuss one point, it is well known that the American Petroleum Institute has published extensive studies on the phenomenon of static generated by hydrocarbon streams of certain kinds. Some varieties of hydrocarbons generate substantial static voltages when moving through tanks and pipes. Numerous fires and explosions have been caused by these sparks. The effect is reproducible and predictable.

We do not profess to know, any more than anyone else, what caused the disaster on the Stanvac Japan. But to lay the blame on magnesium anodes without full justification seems to be unwarranted and unwise.

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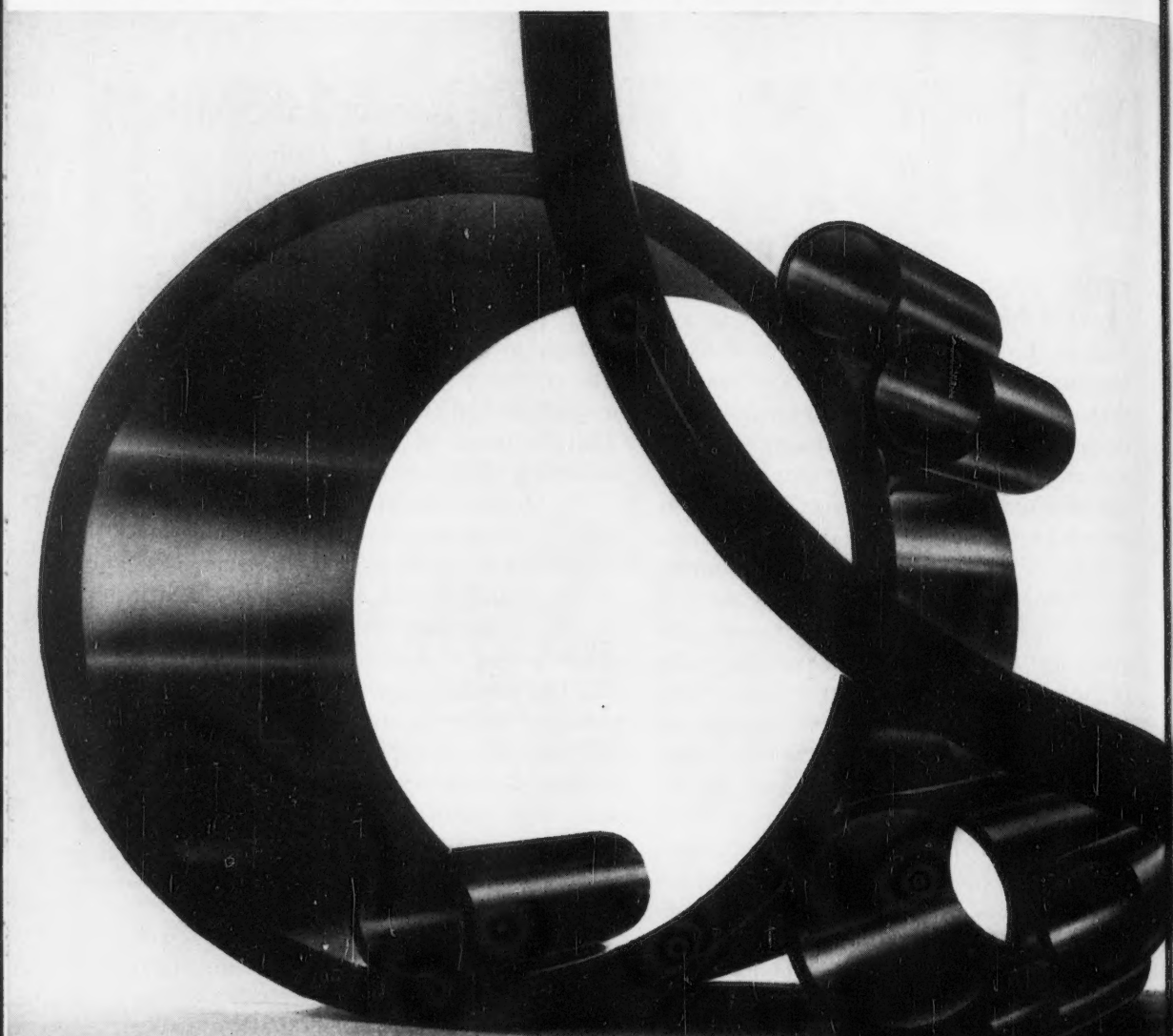

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Pump and Valve Corrosion in a High Temperature Hot Water Heating System*

Abstract

Describes corrosion and erosion on pump impellers and brass valves used in a high temperature, high pressure hot water heating system in Canada. Describes the system, failure of components and laboratory tests conducted to determine cause of failures. Gives recommendations suggested to solve the corrosion problem. 4.6.1

Introduction

PUMP IMPELLERS made of leaded tin bronze valves in a high pressure hot water heating system at the Shannon Park Central Heating Plant in Dartmouth, Canada, were found to be corroding badly. One impeller shown in Figure 1 had been in service only one year. Other impellers were reported to be attacked also.

The Naval Research Dockyard Laboratory was asked in April, 1954, to determine the cause of the corrosion and to make recommendations to solve the problem. This article describes the examination and the recommended solution to the Corrosion Problem.

Description of Heating System

The heating system at Shannon Park was a high temperature, high pressure hot water system in which design pressure of the boiler was 125 psi. Circulating pumps raised the pressure to 160 psi. Temperature of the circulating water after it passed these pumps was approximately 345 F. Steel flow and return lines, each about 3500 feet long, supplied heat and hot water to 521 apartments in 84 buildings. In the system, there were three circulating pumps and about 1000 brass valves. Such heating systems, which are not common in Canada, have been described in detail by Pearce.[1]

Hot water is supplied by three HRT (horizontal return tube), 250 horsepower boilers. Make-up was only 400 gallons per day, and there was no chemical or mechanical deaeration of this make-up water. There were no economizers.

Examination of the System

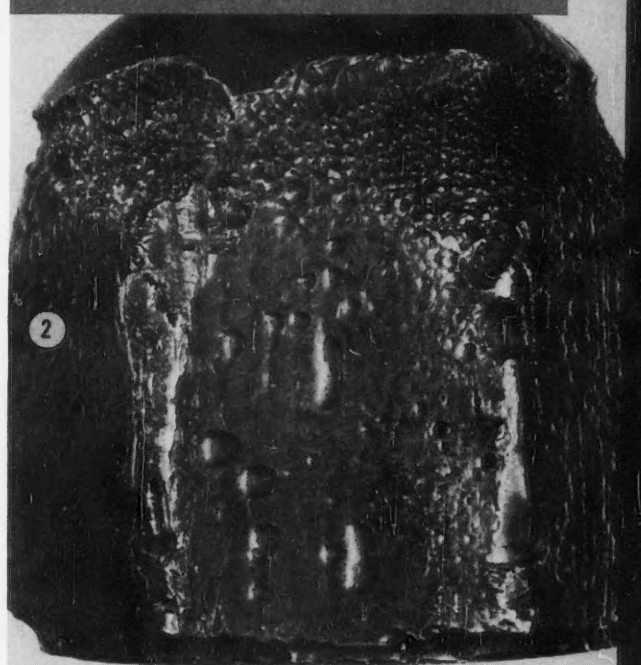
None of the steel, stainless steel or copper components had undergone appreciable corrosion. Only brass and bronze fittings had been attacked at points of high water velocity or turbulence.

Chemical tests were made on the circulating water for presence of oxygen and ammonia. No oxygen was found by the Winkler Test and ammonia was absent when the water was tested with Nessler's reagent.

(Continued on Page 10)

★Revision of a paper titled "Corrosion of Valves and Pump Impellers in a High Pressure Hot Water Heating System" by J. C. Spurr, Dockyard Laboratory, Naval Research Establishment, Halifax, Nova Scotia, Canada.

TECHNICAL TOPICS



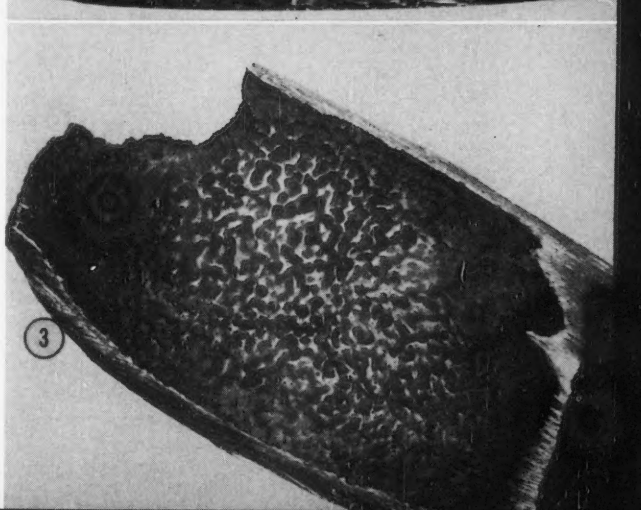


Figure 1—Pump impeller made of leaded tin bronze was corroded badly by impingement attack after one year's service. Figure 2—Impingement attack on nut for impeller shaft. Figure 3—Cross section view of brass valve body showing impingement attack. Some valves had complete penetration.

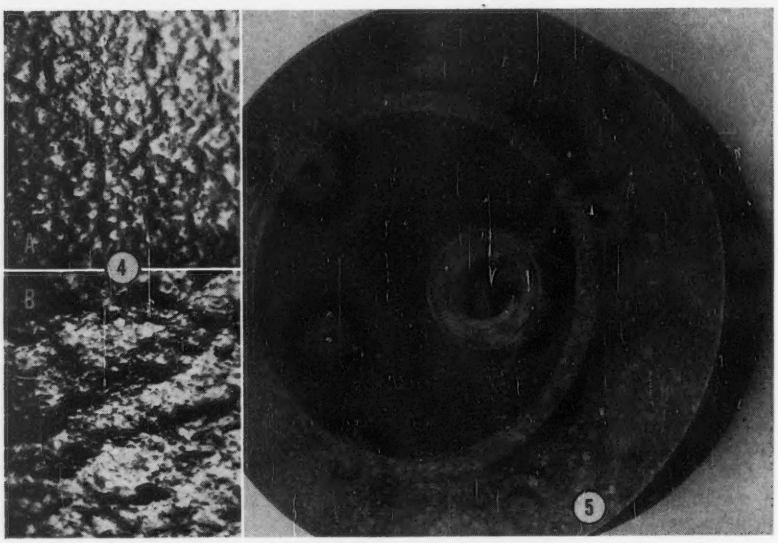


Figure 4—Surface of flange of third gunmetal impeller examined (A) and outer surface (B) of the flange opposite the area shown in A. 70X. Figure 5—Gunmetal impeller after four months' service with the by-pass regulated in the heating system.

Pump and Valve—

(Continued From Page 9)

Solubility of air in water at such a high temperature is low, but if venting at times were imperfect, bubbles of air could be carried along and might cause impingement attack. In the system as designed, the air was periodically vented by valves from the air bottles which were cylindrical vessels welded on the top of the main circulating lines at a number of high points where they trapped air as it passed through the pipes.

The pH of the circulating water in the heating system had been maintained at about 10.5 to 11.0 by additions of caustic soda. After addition of caustic soda was eliminated, the circulating water was analyzed. The results are given in Table 1 with an analysis of the city supply. All results, except pH, are reported in parts per-million.

Apparently lowering the pH caused a calcium deposit in the system to redissolve. This was suggested as a possible explanation of the high calcium content of the circulating water. At a later data, when the pH had again been maintained at 10.5 to 11.0 for several months, calcium content of the circulating water was approximately the same as that of the raw water. Chloride contents of the waters indicated that there was very little loss by evaporation.

When the first examination of the system was made, the by-pass equipment for controlling the temperature of the circulating water was not in operation. After thermometers were carefully checked and put in working order, there was a gain of about 10 F in the circulating water on passing through the pump when the mixing valve was not in use.

Component Failures

Metallographic examination of the impeller (Cu/Zn/Sn/Pb/85-5-5-5) and a failed valve showed no layers or plugs of dezincified metal. The impeller (See Figure 1) was etched on most surfaces that had been in contact with the water as though by general corrosion. The etching was such that grain structure of the metal was revealed clearly.

The nut which held the pump impeller on its shaft (See Figure 2) showed considerable pitting having an appearance typical of impingement attack.

This form of corrosion usually can be distinguished from cavitation by the smoothly rounded bottoms of the pits. Cavitation produces a more over-all jagged appearance. The cause of impingement attack are the erosion of surface films by the impact of air bubbles, with the depolarization of adjacent cathodic areas by the oxygen in the bubbles. Cavitation damage is, according to the usual theory, the result of repeated distortions of the parent metal by mechanical blows struck by collapsing water vapor or steam bubbles. Though the term impingement attack might logically be applied to the impingement of something other than air bubbles, it commonly has been applied to this particular phenomenon.[2]

Several failed brass valves were examined. Main types of failures were serious deterioration of the valve seats (saw-cuts) and what appeared to be impingement attack on the valve bodies, as shown in Figure 3. Some of the valves were useless because of complete penetration. Degree of attack varied in the system and generally was least where the water temperature was lowest.

Preliminary Recommendations

Recommendations found in the literature were made to solve the problem in the following ways:

1. Lowered circulating water pH from 10.5-11.0 to 9.0-9.5.[3]
2. Use of other materials in place of brass and bronze for the valves and impellers.[3, 4]
3. Lower temperature of the water entering the pumps by use of the mixing valve which allowed some of the cooler return water to by-pass the boiler.
4. Use of corrosion inhibitors if the above steps should fail.

Experimental Tests and Results

After preliminary recommendations were made, the following tests were conducted:

Thirty-day corrosion tests were conducted in circulating water using NDHA (National District Heating Association) corrosion testers (ASTM Designation D934-49).

Brass Specimens Used

Brass wire 0.041 inches in diameter and containing 64.6 percent copper (remainder zinc) was used for the coils which served as corrosion specimens. The test period was 33 days. The average corrosion rate for the three coils was 0.003 ipy.

Steel Specimens Used

Diameter of the mild steel wire used for test specimens was 0.050 inches. Test period was 30 days. The average corrosion rate for the three coils was 0.003

During these tests the analysis of the circulating water was approximately as reported above. The pH varied from 9.0

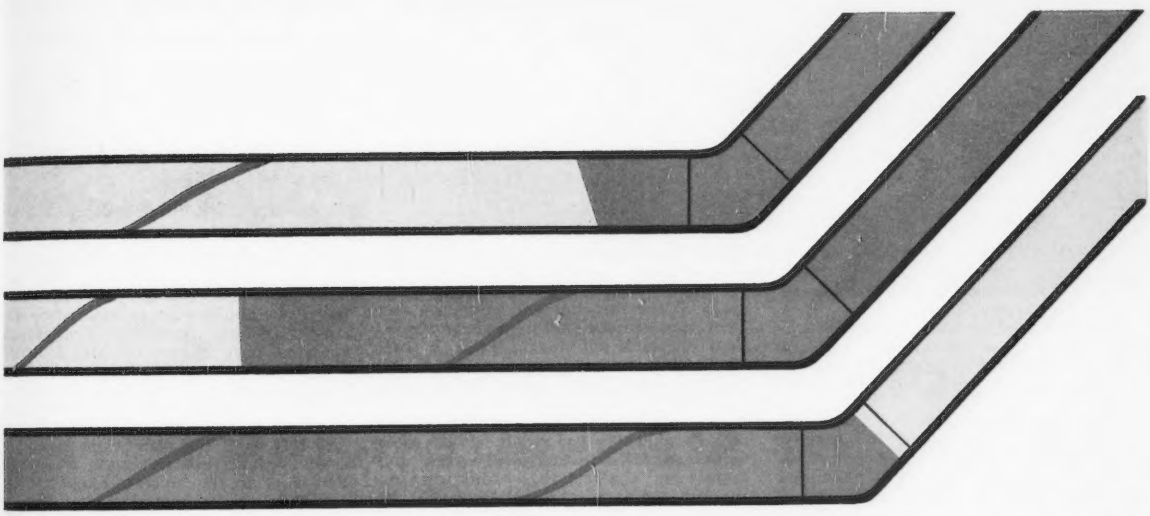
(Continued on Page 12)

TABLE 1—Analysis of Water in System Compared with City Water*

	Mid-Point Main Line	No. 3 Boiler	End of The Line	Dartmouth City Water
Calcium as $CaCO_3$	31.6	24.4	31.6	6.3
Magnesium as $CaCO_3$	Nil	Nil	Nil	2.8
"P" Alkalinity $CaCO_3$	17.8	4.1	17.8	Nil
M.O. Alkalinity $CaCO_3$	26.0	17.8	25.0	4.5
Chlorides as Cl	7.0	7.4	8.0	7.5
Sulphate as SO_4	8.4	9.8	8.6	6.7
Iron as Fe	Nil	Nil	Nil	0.04
Copper as Cu	0.08	0.08	0.08	Not done
Zinc as Zn	0.3	<0.1	<0.1	Not done
Sodium as Na	Not done	Not done	Not done	3.5
Potassium as K	Not done	Not done	Not done	0.45
Silica as SiO_2	Not done	Not done	Not done	1.0
Loss on ignition	Not done	Not done	Not done	11
Total solids	Not done	Not done	Not done	40
pH	10.3	9.4	10.2	6.4

* All units given in parts per million except the pH values.

4-D WROUGHT IRON STEAM RETURN LINES



STEAM CONDENSATE CORROSION: the cause, the effect, and a suggested safeguard

4-D represents the most significant development in the history of wrought iron metallurgy. It was achieved by substantially increasing the deoxidation of the base metal, slightly increasing the phosphorous content and using a more siliceous iron silicate. Result is increased corrosion resistance, improved mechanical and physical properties.

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WHAT CAUSES STEAM CONDENSATE—Steam, losing its heat, turns to moisture as temperature drops below saturation level. This condensate is distilled water, greedy for gases. Any gas in the steam is readily absorbed into this condensate as it cools. The condensate becomes violently corrosive to ordinary piping materials, depending upon the percentage of free CO_2 plus O_2 in the steam.

EFFECT OF STEAM CONDENSATE ON PIPE—Carbon dioxide is the primary cause of return line corrosion. Like oxygen, carbon dioxide is present in all raw waters and may enter the boiler with the feed water. Most of the carbon dioxide found in the steam cycle results from decomposition of the bicarbonate or carbonate content of the boiler feed water. Build-up of insoluble products of corrosion—particularly in smaller lines—may plug the pipe and render it useless. Corrosion may cause grooving, channeling, pitting, completely penetrating the pipe wall.

A PIPING MATERIAL THAT COMBATS IT—New 4-D Wrought Iron is a two-component metal consisting of high purity iron and iron silicate fibers. There are over 250,000 non-rusting glasslike fibers to every cross-sectional square inch. The purity of the iron itself, plus the protection of the iron silicate fibers are a mighty formidable deterrent to steam condensate corrosion and its deleterious effects.

BYERS 4-D WROUGHT IRON

Pump and Valve—

(Continued From Page 10)

to 10.0 and was usually about 9.5. No chemicals were added to the water.

Service Tests on Impellers and Valves

Cast Steel. Testing of special alloys was considered in consultation with the supervising engineer. Cast steel was used because of its relative cheapness and because cast steel valves originally in the system were unattacked. An impeller of this metal was put into service in December, 1954.

The cast steel impeller and some cast steel valves with stainless steel trim, tried as substitutes for a bronze impeller and brass valves, were first examined after 15 and 6 months' service respectively. The impeller was in excellent condition although some very slight attack, having the jagged, honeycombed appearance typical of cavitation damage, was visible on the pump body. Steel valves which had replaced the brass ones showed no signs of deterioration.

Leaded Tin Bronze. About one week before the pH of the cooling water was lowered to 9.0-9.5 in the spring of 1954, a new leaded tin bronze pump impeller was put into service. An examination after about five months showed that there had been considerable attack on all surfaces exposed to the circulating water. The etched appearance noted on the first pump impeller examined was almost eliminated; grain structure was not clearly visible, but surfaces showed the typical rough appearance of metal damaged by phenomena of a mechanical or partly mechanical nature.

A third leaded tin bronze impeller was examined after a little more than one year's service (See Figure 4). Its appearance was similar to the second impeller examined.

After thermometers and mixing valve on the by-pass were put in working order, another leaded tin bronze impeller was installed and was examined after four months. During this period, the operating conditions were as follows:

1. Boiler pressure was maintained at the full design figure (125 psi).
2. Temperature of the circulating water was lowered by means of the by-pass so that it was approximately 20 F lower on the down-stream side of the main circulating pump than it was just before the by-pass, which entered the flow ten feet above the pump.
3. No chemicals were added to the circulating water.

After four months under these conditions except for a cold 5-day period when the by-pass was not used, the hubs, flanges and exterior surfaces of the impeller vanes did not have the very rough surface previously experienced. Interior surfaces of the vanes showed a slight indication of impingement attack, and there was some over-all etching. During this test, impeller weight loss was 0.20 lb. (Impeller weight was 15 lb.)

Discussion of Tests

Gain in water temperature through the pump was ascribed to condensation of steam bubbles at the higher pressure on the downstream side with release of latent heat. This temperature gain, therefore, strongly indicated that damage to the impellers might be caused partly by cavitation and erosive action of steam bubbles. Consequently, steps were taken to evaluate the performance of a pump impeller with the temperature of the water reduced by use of the by-pass to condense steam bubbles before they reached the pump. It was hoped that this temperature reduction would also discourage boiling on the low pressure areas of the impeller and eliminate any cavitation damage that might result from the collapse of bubbles on the high pressure side.

Where protective surface films were removed by mechanical or partly mechanical phenomena, corrosion would add its share to the total damage. Results obtained with the NDHA corrosion testers and the fact that some areas on the brass valves were unattacked indicated that the corrosion rate was low where unaided by mechanical phenomena. When the temperature drop through the pump was controlled, steam bubbles would have been eliminated, but not air bubbles. Water velocities would have remained high. Therefore, impingement attack and turbulence probably were still major factors in the corrosion that occurred during the test when the temperature drop across the pump was controlled.

The rough impeller surfaces previously experienced were prevented by elimination of conditions favoring presence of steam bubbles which probably would contain traces of oxygen) by controlling temperature with the by-pass. Lowering the temperature of water entering the pump theoretically would necessitate a lower pressure on the low pressure areas of the impeller vanes to produce cavitation. The fact that lowered water temperatures eliminated rough impeller surfaces indicated that conditions resulting in erosive action of steam bubbles and possibly cavitation had been eliminated.

Weight loss from the impeller, during the test when the temperature drop was controlled, was roughly uniform over all surfaces (See Figure 5) and indicated that under these conditions a service life could be expected three times that obtained when the by-pass was not used, or about three years.

A few cast steel valves originally had been used in the circulating water system close to the boilers. These and the cast steel valves installed later were in perfect condition when examined in 1958. The cast steel impellers also were in good condition. Life of the cast steel impellers is estimated to be a minimum of 10 to 15 years.

FOCUS ON COATINGS
Five articles on coatings will be featured in the June Technical Topics Section. A wide variety of coatings topics will be included.

Conclusions

1. Results of the plant tests indicated that impingement attack and erosive action of steam bubbles were major factors in the corrosion-erosion of the impellers. Cavitation probably played a part.
2. Corrosion also played a part after protective surface films were removed by phenomena that were mainly mechanical in nature.
3. Damage to brass valves and the nut appeared to be impingement attack, probably resulting from imperfect venting of air from the system.
4. Cast steel impellers and cast steel valves with stainless steel trim have been very satisfactory substitutes for the bronze impellers and brass valves.

Acknowledgment

Acknowledgment is given to the Defense Research Board of Canada for permission to publish this article.

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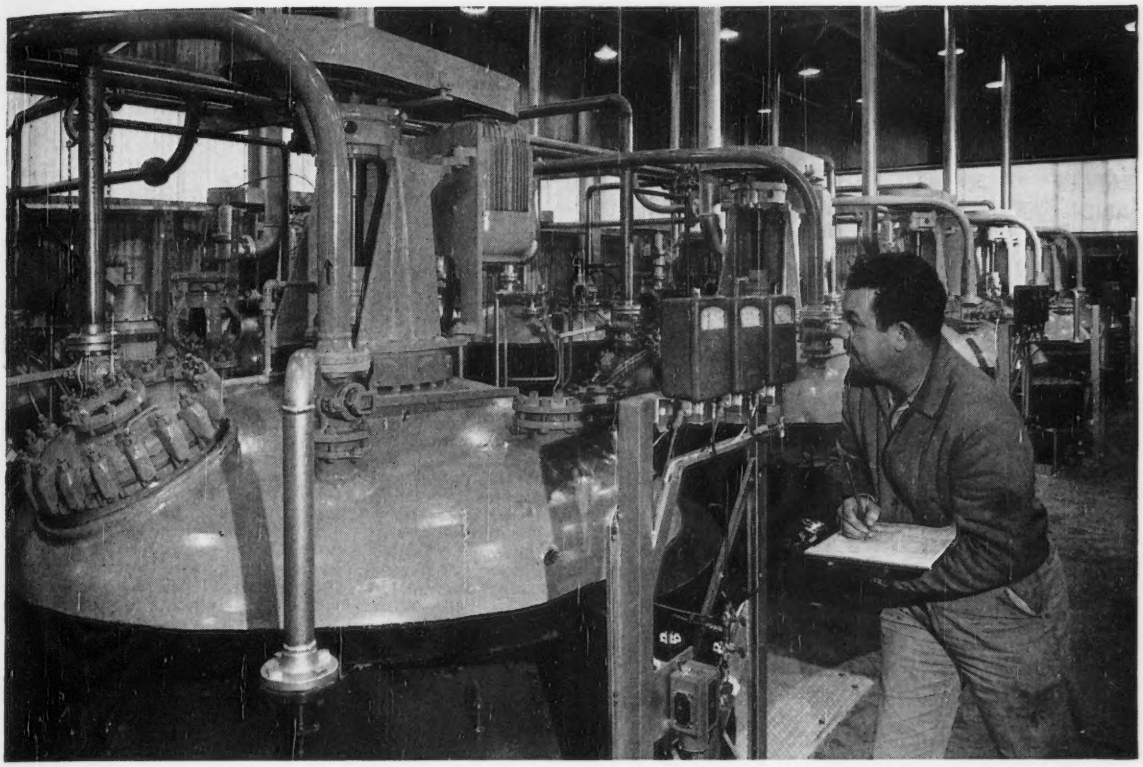

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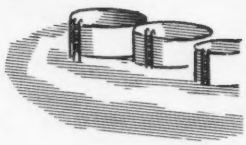

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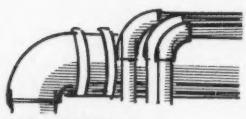

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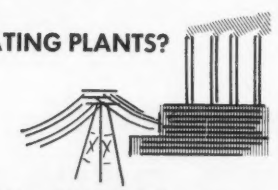

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Polyethylene pipe accounts for over 65 percent of the market in the United States. Acrylonitrile butadiene-styrene (ABS) and rigid vinyl pipe account for approximately 20 percent and 10 percent of the market respectively. U. S. commercial standards have been developed for these types which are available with the National Sanitation Foundation's seal of approval, indicating that they are suitable for conveying potable water.

Uses of plastic pipe range from water mains to acid and hot oil service. Specific types have been developed also for high temperature and high pressure service.

Thousands of miles of plastic pipe are giving satisfactory service. More than 50 miles of schedule 120 Type 2 rigid polyvinylchloride pipe is being used in wash down systems on U. S. Navy ships. A firm in Holland has installed over 230 miles of rigid vinyl water mains and over 30,000 house connections without major difficulties. Type 2 rigid vinyl pipe also was used in a 15-mile irrigation system at Santa Paula, California. This pipe permits distribution of liquid fertilizers and insecticides with the irrigation water.

Over a thousand miles of ABS pipe has been used for gas transmission lines. Similar pipe used in a rotary filter handling acids, ferric chloride and sludge is operating satisfactorily after 11 years' service for the Sanitation District of Chicago.

In England, many miles of 5-inch polyethylene tubing have been produced for emergency use. During a drought in the summer of 1959, a one-mile section was laid in six hours to provide the city of Manchester with an additional 500,000 gallons of water daily.

If rigidity is essential and high density polyethylene or polypropylene is not available, ABS pipe should be considered. If the line is permanent, fittings can be cemented with solvent. Otherwise, threaded fittings applied with a strip of polyfluorocarbon should be used. Despite difficulties associated with joining, the use of low temperature polyethylene tubing is recommended whenever it is serviceable.

Spiral wound monofilament reinforced epoxy resin pipe usually can handle high temperature and high pressure service. After seven years' service, about 80 percent of mat reinforced plastic pipe is still in use. For example, 1000 feet of epoxy resin pipe was used to carry flue gas to a treatment plant at a generating station at Battersea, England, and one mile of 40-inch reinforced polyester pipe is used to discharge acid waste water at Monsteros, Sweden.

Other case histories show excellent service results with nylon pipe in hot oil service, polyfluorocarbon pipe in hot acid and solvent service and impregnated graphite in hot corrosive service.

Plastic pipe can be laid in long lengths from coils so that few fittings are required. Because it is advantageous to minimize the number of fittings, the use of low density polyethylene pipe is recommended whenever possible.

Solvent welded fittings are as strong as the pipe itself and should be used on ABS and vinyl pipe when the installation is permanent. Threading plastic pipe reduces strength but makes versatile piping systems possible. The joints can be made tight by inserting a strip of polyfluorocarbon.

Flanged plastic fittings can be solvent-welded on ABS or vinyl pipe and can be cemented on reinforced pipe. Although dissimilar plastics do not create galvanic cells as dissimilar metals often do, standardization on fittings and valves is recommended. Despite high material costs, valves of chlorinated polyether should be considered because they are resistant to almost every corrosive and many solvents found in the chemical process plant.

★ Extracted from a paper titled "Plastics vs Corrosion" by Raymond B. Seymour, Alcylite Plastics & Chemical Corp., Newhall, Cal., (now at Sul Ross College, Alpine, Texas) presented at meetings of the San Francisco, Seattle and Portland Sections, National Association of Corrosion Engineers, November 10-12, 1959.

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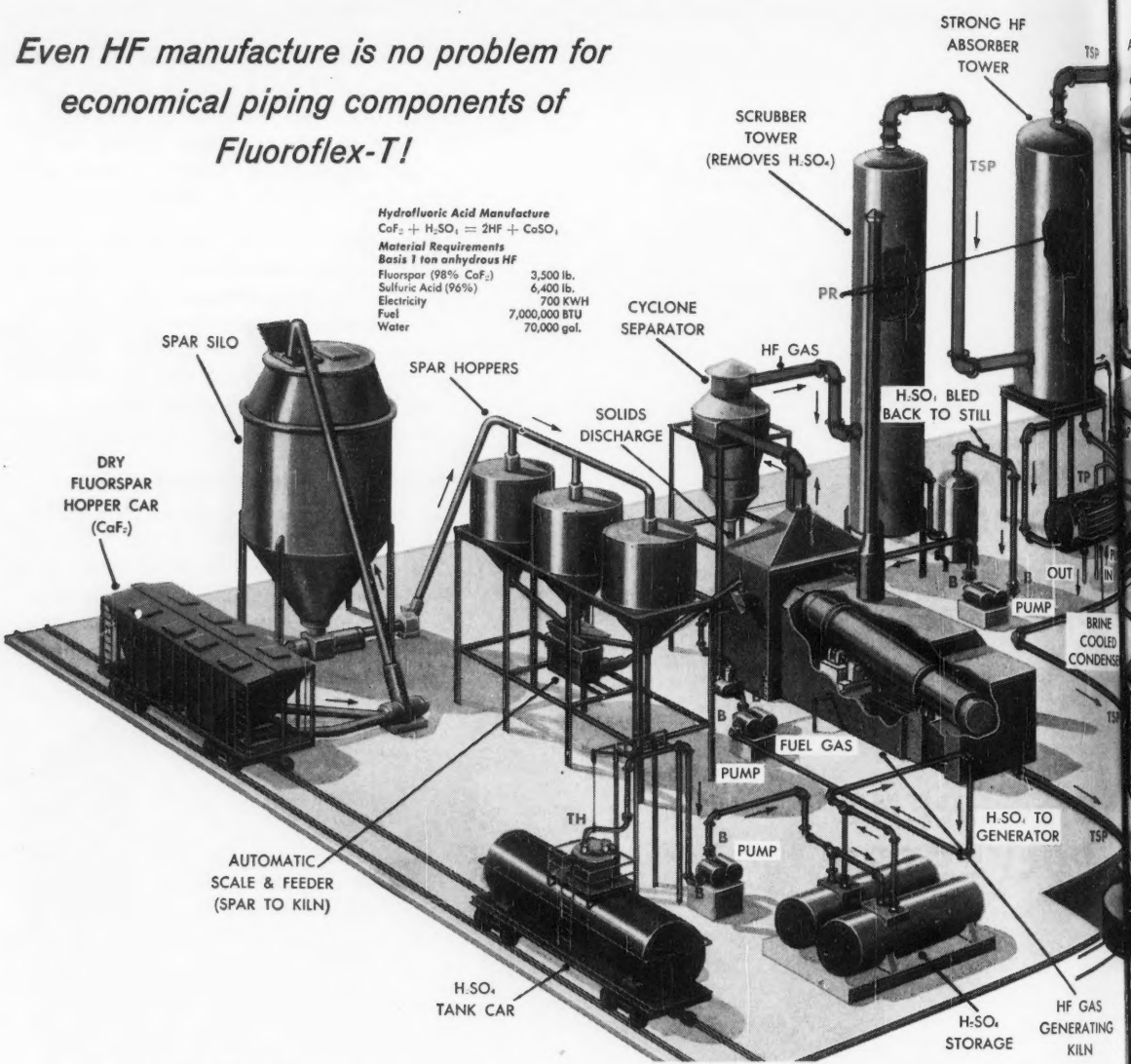

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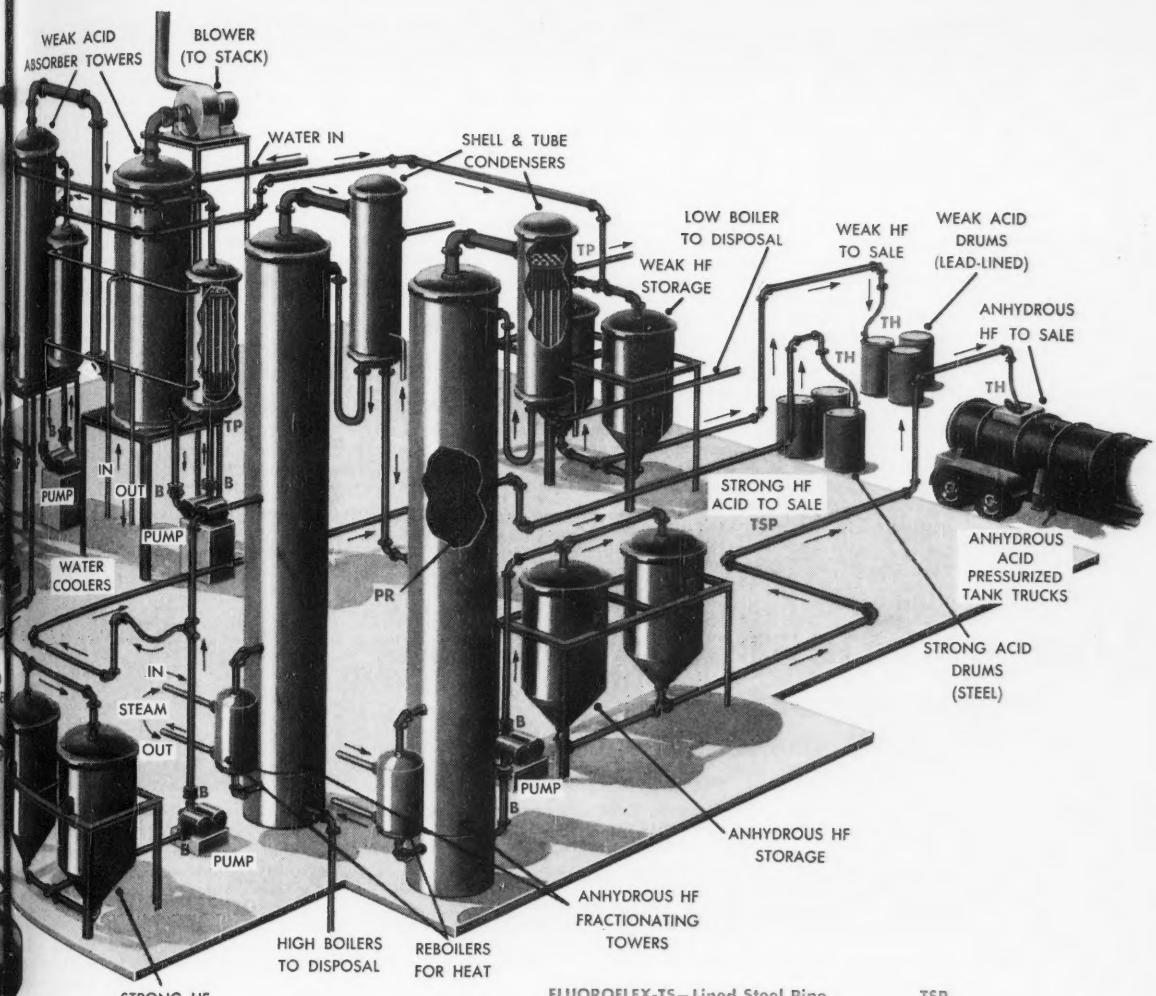

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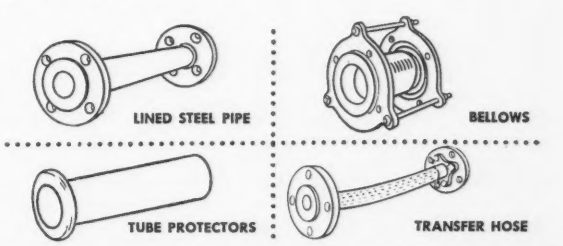

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Use of Chemical Resistant Masonry

Abstract

Briefly discusses types of masonry used for chemical resistance and kinds of mortars commonly used. Presents engineering design problems with drainage trenches, sumps, foundations, various vessels, towers, neutralization clarification installations and chimneys. Discusses operational problems which should be considered in design such as personnel indoctrination, changes in plant processes, fast maintenance of equipment and product quality control. 6.6.5

MOST CERAMIC materials such as porcelain, brick and silicate cements, when used in corrosive environments, resist these attacks completely or not at all. Such considerations as stress and intergranular corrosion, weld problems, electrochemical corrosion and crevice problems are not pertinent.

Ceramics such as porcelain and chemical stoneware have the recognized disadvantage of low resistance to thermal shock, brittleness and porosity. Fortunately, some of these factors can be controlled or minimized. For example, glazing will minimize the porosity problem; some ceramics can be glazed to the point of having no adsorption.

Physical properties and chemical resistance of most ceramic materials can be varied by changing the contents and by varying firing processes. For severe thermal shock applications, chemical stoneware is made with high percentages of silicon carbide. For milder applications, fused silica is introduced. For a denser body, grog size is decreased. In some cases where a slight porosity is desired for surface requirements, underfiring is used to effect the change in physical properties.

If fireclay brick must withstand severe thermal shock, the brick is made with porosities as high as 17 percent. For moderate resistance to thermal shock, the porosity is about 6 percent.

Physical properties of red shale brick can be varied by changing particle size, porosity, etc. Generally, this type brick is used for economic reasons, high density and where a higher percentage of iron and more susceptibility to thermal shock are not important.

Carbon brick is used where exceptional resistance to acids, alkalies and thermal shock is required. Although this brick lacks resistance to oxidization, glazes sometimes can be used to prevent it.

Kinds of Mortars

Silicate Mortars

Two main types of silicate mortars are characterized by their manner of setting. In one the viscosity is raised and hardness developed by loss of water. The second type contains substances which react with the silicate solution and cause a setting action based on gelation of the colloidal silica with little or no loss of water during the setting action.

Although many relatively inert materials can be used as fillers or matrices in silicate mortars, quartz is commonly used because it is inexpensive and highly resistant to most acids. Sodium fluosilicate, a common setting agent for acid resistant mortars, reacts with the sodium silicate solution to form gelatinous silica which acts as the bonding agent.

These mortars are not resistant to water because of the formation of alkaline solutions which attack the silica bond. For the same reason, these mortars are not applicable in alkaline environments.

In sulfuric acid service where the acid dries in the brickwork, mortars based on potassium rather than sodium silicate are preferred. One reaction product of sulfuric acid with the sodium based mortars is sodium sulfate which can form hydrates, a process which can result in disruptive expansion.

Sulfur Mortars

Sulfur mortars commonly are composed of sulfur, an inorganic filler and an agent to interfere with orderly crystallization. This agent generally is a polysulfide, often referred to as a plastizer. Small amounts of carbon black can be added to increase workability, retard settling of the filler and increase tensile strength.

Although highly resistant to strong acids, sulfur is attacked readily by strong or weak alkalies to form sulfides. It is also attacked slowly by air, especially moist air, to form sulfur dioxide and other oxygen containing compounds. It reacts with numerous metals, rather slowly with iron and is rapidly attacked by chlorine, anhydrous ammonia and many organic solvents.

Phenolic Resin Mortars

The phenol-formaldehyde mortars, some of the oldest commercially used synthetic resin types, have good acid resistance but poor alkali resistance. The corrosion resistance of a resin or other high polymer is dependent on three factors:

1. Its structure should be tight enough to prevent flow through the molecular network. For example, water can easily flow through uncoated cellophane because of small molecules in the water, but giant dye molecules are held back. For corrosion resistance of a resin material, the molecular holes should be so small that the corroding molecules do not flow through.

2. Molecular structure should have as few reactable groups as possible, such as reactive hydroxyls, carboxyls, sulfonic acid groups, amino groups, etc.

3. Molecular bonds should be strong because destructive chemical attack is accomplished only by the breaking of bonds. This accounts for the remarkable resistance of polytetrafluoroethylene and for the chemical stability and lack of toxicity of chlorofluoro-carbon refrigerants. Groups like ether linkages, hydrogen attached to carbon, fluorine attached to carbon and carbon attached to fluorine resist chemical attack. The good resistance of carbon-carbon and carbon-hydrogen bonds is exemplified by poly-ethylene.

Even though tight networks are attained, acid hydroxyls formed after polymerization of phenol with formaldehyde give points of surface attack with alkalies. A phenolic for resistance to alkalies is manufactured by partly polymerizing the phenolic resin and then using a chemical reaction to convert the acidic phenolic hydroxyls to non-acidic aliphatic or alcohol type hydroxyls which are more resistant to alkali attack.

Furan Resin Mortars

The furfuryl alcohol resins generally are polymers of furfuryl alcohol or of furfuryl alcohol and formaldehyde. They have good acid and alkali resistance because the structure is dense and there are few reactable groups left after polymerization.

Engineering Design for Masonry

Most installations of chemical resistant masonry can be designed on the following five fundamentals:

1. The supporting steel or concrete structure should be designed to take the full load, generally in the form of tensile stress so that adequate safety margins are allowed.

2. In most cases an impervious interliner should be used between the supporting structure and masonry lining. The interliner withstands the corrosive conditions at its surface, at highest operating temperatures on the inside of the interliner when the outside air temperature is highest.

3. Chemical resistant masonry should resist the chemical, mechanical and temperature conditions and should be thick enough to provide the temperature drop required for the interliner under maximum conditions.

4. Where possible, masonry should be designed so that brickwork is under compression and not in tensile stress. Where brickwork is in tension, adhesion and material strength should be adequate for the maximum stresses.

5. Long and high vertical walls where temperature, agitation or sulfur cements are used should be bowed and/or pitched outward so that compression will not tend to bow the wall inward.

Drainage Trenches

Trenches should be designed carefully with optimum construction ratio of the width twice the height. Minimum recommended slope is ¼-inch per foot. Width inside the impervious interliner should be such that a minimum of brick cutting is required when standard shapes are used. Top edges of the wall should be designed

(Continued on Page 20)

★Revision of a paper titled "Chemical Resistant Construction With Masonry and Ceramics from the Chemistry Standpoint, the Engineer's Standpoint and the Operator's Standpoint," by Robert R. Pierce, Pennsalt Chemical Corp., Natrona, Pa., presented at the 13th Annual Conference, National Association of Corrosion Engineers, March 11-15, 1957, St. Louis, Mo.

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Chemical Resistant—

(Continued From Page 18)

so that duct boards can be used to protect personnel.

Expansion Joints

Expansion joints should be designed to prevent weak points in the interliner over expansion joints in the concrete. In construction, the lower part of the wall should be installed first and then the floor so that the floor brick lock the wall brick. Experience has led to preference for a properly primed ⅜-inch modified oxidized asphalt interliner with two layers of coated glass imbedded in the interliner.

Sumps

The engineering approach to the sump is almost the same as that to trenches. Where there is heavy agitation in the sump, brick wall thickness should be increased generally by installing two layers of brickwork in place of a single layer. Where the structure is rectangular or square and large sizes and/or high temperatures are involved, one or more of the following designs should be used to prevent any inward collapse of the brickwork:

1. Sump walls should be bowed outward and the bottom dished.
2. Walls chamfered so that inside dimensions of the top are longer and wider than the bottom.
3. Pilasters used in the walls to cut the length of long straight runs of brickwork and concrete.
4. Metal fasteners of proper design and spacing used to join brickwork and concrete.
5. Use of properly designed and placed expansion and contraction joints in brickwork.

Design should be considered so that the sump is not physically tied to the building, thus preventing the passing of building movements as stresses to the sump. Where the water table is above the bottom of the sump's base, water drainage must be provided below the sump bottom during construction. This will prevent water pressure in the concrete, forcing the interliner off the concrete before the brickwork is installed.

Neutralization Clarification Installations

Neutralization clarification installations differ from sumps in size and the need for intimate mixing of materials such as neutralization agent with acid waste. This mixing is accomplished by use of baffle walls in large troughs or vessels and agitators in the system to keep the sludge from settling. In such vessels, it is important to consider either bowed, chamfered or pilastered walls due to size. Baffle boards should be set in slots provided by corbeling the brickwork; each corbeling should be no greater than 2 inches. If the lining does not extend as high as the concrete wall, it is important to flash over the masonry lining surface so that water cannot get between the concrete wall and the lining when the vessel is empty.

Chimneys

Where several thousand cubic feet of corrosive gases per hour must be removed, these gases must be exhausted high in the air to prevent a nuisance. The best construction for exhaust of these gases is a double column with the outer column constructed of concrete or masonry of an appropriate structural design to take the wind load, sun load and ground movement. The inner column should be acid masonry construction to handle the acid gases. The inner column is sometimes set in a lead pan with weep holes to drain acid condensation away to prevent damage to the foundation. This construction is necessary in place of steel stacks for handling combustion gases in the dew point range.

Foundations and Piers

The best method for building foundations and piers is to construct the required shape completely with chemical resistant masonry. This design avoids three trouble points: shaping of the interliner around corners and edges, holding the outside brick sheathing against vibration and impact and the sealing of the anchor bolt holes. If the foundation or pier is built of acid brickwork, the impervious interliner on the concrete floor can be applied without weak points. The entire block will be acid, impact and vibration resistant. There is no necessity for sealing the anchor bolt holes. Brick and cement should be chosen for maximum adhesion.

This same construction composed entirely of acid brickwork can be used as tank supports. If the tanks are placed on top, brickwork can be covered first with the proper chemical resistant mortar premixed with dry ice to slow the hardening action. The tank then will settle on the soft cement. Later, when loaded, the mortar will have hardened, thus equalizing the load.

For support of tanks which will leak a great deal, acid brickwork ribs should be used with a heavy slope to the acid brick floor so that spilled material will flow readily from between the ribs.

Cradle foundations of acid brickwork are a good investment for horizontal clyindrical tanks in corrosive services.

Process Vessels

Process vessels must be designed fundamentally to resist chemical conditions involved and stresses due to temperature and pressure. The vessel and its lining must withstand compressive and tensile stresses coming through maximum and minimum operating and temperature conditions. Rectangular or square tanks must be reinforced on the outside to prevent wall vibrations or bulging. Riveted tanks have obvious disadvantages; welded construction is almost mandatory. Out-of-roundness of cylindrical tanks must be minimized to ½ percent of the difference between the maximum and minimum diameter at any cross section along the length in high temperature and pressure vessels.

Over 20 impervious interliner materials can be considered for use between vessel and lining of brickwork.

Brick lining thickness must be sufficient to lower the temperature to the limits of the interliner when the vessel is operating under maximum temperature inside and when the vessel's outside temperature is at a maximum. The vessel always should be placed on foundations to allow air passages underneath so the interliner will not be affected by accumulated heat on the bottom of the vessel and so that the brickwork on the bottom will not be thrown into heavy tensile stress by the difference in the coefficient of expansion of the structure and the masonry lining.

In European process vessel design, the brick lining is commonly pre-stressed so that it always will be under compression under all conditions, so that the linings can be thinner and, in many cases, so that the impervious interliner can be eliminated. Added advantages are increases in vessel capacity and maintenance lowered to a point where inside maintenance is almost eliminated. The first such pre-stressed lined vessel was installed in this country in 1955.

In simple operation for normal construction as now practiced in this country, one

course of brick is sufficient. Where heavy agitation, heavy abrasion or high temperatures and pressures are present, usually two courses of brickwork are desirable. Inlets and outlets must be designed to protect the interliner, usually by ceramic sleeves or brick linings. Inside diameter of inner lining of inlets or outlets should correspond to the inside diameter of the pipe to which it is to be connected. In all cases the outside of the vessel should be adequately protected.

Storage Vessels. In many cases, it is desirable to construct large storage vessels for chemical solutions in the course of process or dry finish chemicals. Design factors generally follow those described above. Plants have found an advantage in using tile liner-plated concrete tanks for moderately corrosive conditions. One plant has built over 40 such vessels holding about 10,000 gallons each. These glazed tile liner-plates are about 9 inches by 12 inches by 1½ inches with several dovetailed grooves on the back. They can be bonded on the sides by a special technique and chemical resisting mortars with the concrete being poured on the outside of the liner plate. Sometimes liner-plate linings are used inside a cylindrical steel tank with about 4 inches of a portland cement grout between the tile and steel. Also large hollow tile is used to build large silos for storage of dry chemicals. These are often less expensive to build than a steel or concrete vessel.

Towers. In tower construction for gas and liquid contact work, vertical stresses in the lining must be considered because of the height. Other factors in tower design are similar to those for other process vessels. It is possible to construct gas contact towers using a double brick wall with an air space between to eliminate the steel or concrete structure

Operational Problems Considered in Design

Several operational factors should be considered when construction with chemical resistant masonry is being designed. These factors are concerned with personnel indoctrination, changes in plant processes, fast maintenance and product quality control.

Personnel Indoctrination

Possible abuse of construction and equipment by operating personnel should be considered during design. Such abuse often can be prevented by proper indoctrination of personnel through operating manuals or some printed instructions.

An example of equipment abuse by personnel who were not properly informed occurred at a plant where an acid brick and mortar sheathing, designed for hydrochloric acid and carbon tetrachloride, was placed on a concrete pad. This sheathing was subjected to caustic soda and hydrofluoric acid resulting in fast deterioration.

Masonry linings tend to shrink when left dry and out of use for long periods. If left dry, these linings go into tensile stress and often crack when returned to service. They should be left full of an acid or suitable liquid when not in operation.

Changes in Plant Processes

Often a different set of chemical and physical conditions are encountered in the plant processes than were anticipated in research or pilot plant tests conducted before design and construction. If these changes are anticipated and considered in the original design, long range savings often can be made. Examples of this are given below:

A plant operated a chimney for a boiler using coal as a fuel. The chimney was

(Continued on Page 22)

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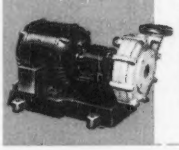

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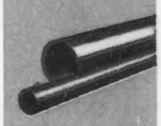

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Chemical Resistant—

(Continued From Page 21)

used to handle combustion gases with a stack gas temperature of 450 to 550 F for 39 years. The chimney was an open riveted construction with a brick lining of an unknown cement, probably fireclay. As an economy move, the fuel was changed to Venezuela oil containing a high sulfur content. Some of the combustion gas heat also was used before discharging the gases to the chimney. This use of heat lowered the combustion gas temperature to about 300 F, which is in the dew point range. The stack lining and upper portion of the stack's steel failed in one year after the fuel and heat change. Steel in the top of the stack was gone completely. Steel under the soil in the breaching, which was not lined, had shown a 3/8-inch thickness the year before; after one year at the lower temperature, holes could be punched with the finger through the steel in the breaching bottom.

Intermediates should be considered when pilot plant or research conditions will not give full information. For example, a plant was designed on pilot plant work with a bed salt as a raw material. Later, when a solar dried sea salt was used, bromines became a factor requiring changes in the masonry.

Often a particular set of chemicals and temperatures are given as the corrosive environment. Later it is found that the intermediate chemicals should have been considered. In chlorination of an alcohol, 17 intermediates were possibilities in addition to the original alcohol, chlorine and the end product. If such factors are not given consideration, interrupted production and high maintenance costs can result.

Some process areas typically change every few years and should be designed for probable changes. The operating department will be more flexible if the original design is such that equipment will be able to handle acids and alkalies.

Fast Maintenance

Special mortars with fast hardening times are available which make possible fast repairs. Brick used for fast repairs should be brought inside where they can be warmed to room temperature, dried and cleaned before use.

Product Quality Control

Masonry linings can effect product quality. Proper use of brick sheathings can cut down dust in a plating plant and therefore improve the plating. Glazed tile can be used in textile bleach vats to prevent fraying of the cloth when the cloth is removed. Carbon brick and carbon filled resin mortars can be used as linings to maintain the pure water required in modern high pressure steam operations. High density brick and resin mortar linings are used to prevent inter-batch contamination in dye-stuffs operations.

Improper choice of materials can lower product quality also. For example, in several cases, brick with a high and available iron content has been used in hydrochloric acid systems with high iron contents in the hydrochloric acid resulting.

DISCUSSIONS

Question by Robert B. King, Heil Process Equipment Corp., Cleveland, Ohio: Why should a sodium silicate cement not be used with sulfuric acid environments?

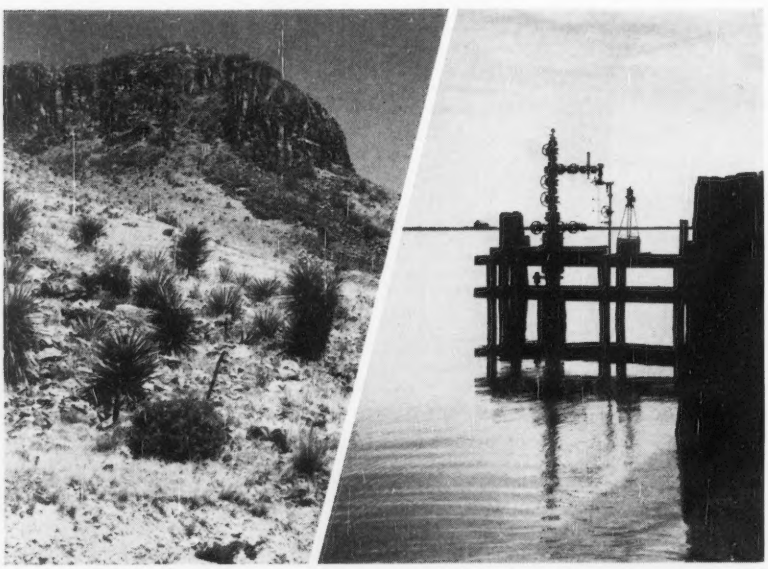
Reply by Robert R. Pierce:

Sodium silicate cements have been used successfully for 34 years in sulfuric acid environments. There are a few border line areas where other chemical resistant mortars will be more satisfactory than sodium silicate cements in sulfuric acid environments. Resin type mortars should be used where the conditions in the process will be alternately acid and alkaline. Resin or sulfur type mortars should be used where crystals are formed in the process. Resinous types of mortars should be considered where the acidity will be weak and where the pH will be continuously above 5.5. Resin mortars should be used where steam will be directly impinged on brickwork surfaces. Potassium silicate mortars which do not use any fluorides in the hardening system should be used where sulphuric acid will alternately wet and dry in brickwork such as in chimneys and Gay Lussac or Glover Tower Construction. Resinous types of mortars should be used where highly agitated abrasive slurries will impinge on the brickwork. In most other conditions in sulfuric acid work sodium silicate type mortars can be considered.

Question by Peter A. Kahn, Metcalf & Eddy, Boston, Massachusetts: Is standard method available for testing acid resistant cements at elevated temperatures?

Reply by Robert R. Pierce:

At the present time, a test method is available which can be used to test acid resisting mortars in any environment and temperature. This tentative ASTM test method is entitled "Proposed Tentative Method of Test for Chemical Resistance of Mortars."



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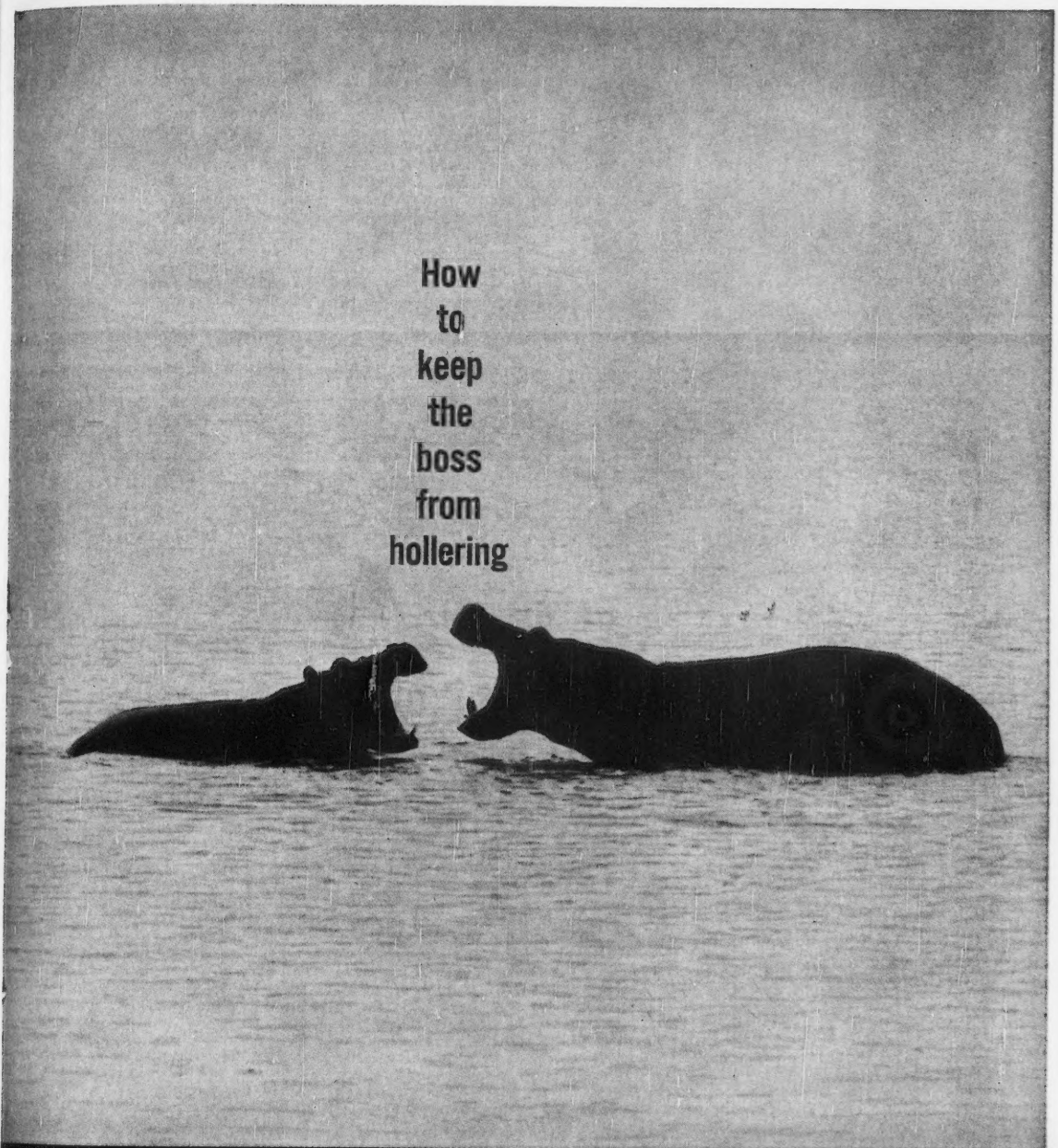

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Abstract

Discusses certain species of wood that are known to resist decay and deterioration. Presents qualities of wood that give the species resistance to acid and decay. Explains role of sapwood and cell structure in relation to usefulness of certain species in combatting chemical attack. Tabular data give resistance of woods to various chemicals. 6.6.11

Characteristics of Woods Used to Handle Chemicals*

CERTAIN WOODS always have been associated with certain uses ever since man has been able to go into the forest to cut down trees and found that some are harder than others, some are tougher than others and some are prettier than others.

There is a long association of hickory for axe handles, ash for baseball bats, rosewood and cocobola for knife handles, ebony for piano keys, walnut for gun stocks and so on as man chooses the best wood for a particular purpose and a particular use. The choice is based on the properties the wood normally has, its availability, economy of its purchase and, most of all, on the fact that it does the job for which it is intended.

Besides the common uses of wood, certain species and grades of these species are known to resist decay and deterioration better than others. Information is given here about the lumbers now available at reasonable cost that are suitable to do a job satisfactorily and that have structural strength in addition to being highly or moderately resistant to various chemicals, gases and fumes that usually are very destructive to other materials.

Certain woods used in their natural form outlast others and also outlast steel, concrete and many other construction materials in the same service.

Acid and decay resistance of wood species are a function of (1) high cellulose content, (2) high lignin content and (3) low pentosan content. The formula used generally by research laboratories to predict the relative acid resistance of a species is:

Cellulose content **plus** lignin content **minus** pentosan content. The higher the resultant figure, the greater the resistance.

Cell structures of some woods contain natural resistance in the form of oils and resins. These include tank woods that are available in quantity and quality in pieces and timbers of such a size that they are economical to purchase in the form necessary for industry.

Four woods are commonly used by tank builders: Tidewater red cypress, long leaf yellow pine, California redwood and yellow Douglas fir—all of which are available commercially at a reasonable cost in various grades.

While this article concerns heartwoods of these species particularly, it must be borne in mind that all contain certain amounts of sapwood.

The best grade in tank building lumber is clear heartwood or tank grade. Other grades are often used when the clear grades are not available and where gases, not liquids, are stored or transported. When knots, termed the sound red variety, are present, they do not reduce the resistance to decay below that of a piece of clear lumber of the same species.

The term "clear" is used here to mean the piece is free from sapwood, not only free from knots. This statement should be understood fully because any sapwood of any species has little if any decay resistance.

Usually, trees of the yellow pine variety are tapped for turpentine. Trees that are not tapped are known to the trade as being unbled so that the terpene and pich remain in the cell structure and make the lumber very heavy and comparatively dark in color. It is generally proved that this very heavy pine from unbled trees is not much more resistant to chemical action for general purposes than the lumber that comes from bled trees of what are classified as normal long leaf pine with a weight of approximately 4½ pounds per board foot green. The weight of unbled pine often exceeds 6½ pounds per board foot, and pieces of the unbled pine will not float in water.

Yellow pine of the short leaf variety is a fast growing wood with the spring growth containing little, if any, of the terpene so prevalent in long leaf variety. This type of wood is more readily creosoted and impregnated. The open cell structure allows the impregnant to enter and fill it.

Short leaf pine can be impregnated or creosoted to suit a variety of conditions or to make it resistant to specific chemicals just as paints and coverings can be selected to prevent or retard corrosion.

Preservatives of the creosote type have much in common with tannins and phenolic extractives usually drawn from wood in contact with hot water. Therefore, the creosote will begin to "bleed" or be extracted by hot water to the depth of penetration of the heat. This can be determined by the manner in which the piece is impregnated, that is, whether it is immersed completely and subjected to the preservative on all six sides or whether it is subjected to the heat on one face only.

In short tests with different species of woods, particularly those such as yellow pine that contain terpenes, these terpenes protect the wood fibers by polymerizing or uniting with the solution to which the pieces have been exposed. In time, this action will be nullified by the increased attack of the acids on the wood.

Heartwoods of Tidewater red cypress and longleaf yellow pine have little need for preservatives because both contain oils and terpenes that completely fill the cell structure, making impregnation difficult even by pressure.

Two good Western woods used with great success are California redwood and Douglas fir. The lumber can be economically supplied in clear all-heart grades.

Redwood and fir are endowed with natural substances in their cellular structure that enables them to resist deterioration. Redwood has resins and tannins in the heartwood; Douglas fir has an ingredient called **toxifolin** that not only is decay resistant to a certain extent but also has slight fungicidal properies.

For some chemicals, particularly sulfuric acid and sulfur gases, Douglas fir is preferred because it has greater structural strength and is available in large timbers of longer length, eliminating the need for end splicing.

The sapwood is called alburnam and generally is light, almost whitish in color, and grows on the outside of the tree between the heartwood and the cambium and wane.

In most woods, sapwood is considered inferior and generally not as good as the heartwood. An exception is white maple which might be termed all sapwood and commands the highest premium.

A piece of wood that is tight in its cellular construction resists chemicals and fumes with which it comes in contact. Because all wood is hygroscopic to a certain extent, the less penetration into the piece, the longer the piece will last.

A knot of the sound red or tight variety is found where a live branch is present. While red or tight knots have little or no detrimental effect, a black or unsound knot is detrimental; the piece with such a knot should not be used. Similarly, a split or a shake causes wide openings that allow gases or liquids to attack deeper causing premature deterioration, so they should be avoided in good construction.

Checks caused by drying usually close up when the wood is wet and are not very detrimental unless they are excessively deep and wide. When units are built to store liquids or to transport fumes, metal banding or tie rods keep the wooden parts together tighly so that corrosive action is confined to one side of the piece only.

Table 1 shows resistance of woods to various chemicals. It gives general information on what to expect when using a certain species of wood. This chart shows that heated liquids attack wood cells more rapidly than cold liquids or liquids at room temperature.

It is not expected that anyone but a specialist in wood tank and wood fabrication could properly choose the right wood and design a unit that would be satisfactory. Building and fabrication of wood for corrosion resisting units is the job of a specialist.

New wood impregnants being tested by Arrow Tank Company are classified as KO series.* They are acid modified phenolic systems in an alcohol and water medium and are cured by baking the

(Continued on Page 26)

★Condensation of a paper titled "Wood as a Material of Construction for Tanks, Stacks and Engineered Corrosion Resistant Products" by Arthur P. Pfeil, Arrow Tank Company, Buffalo, N. Y.

* "Wood Tank Engineering," a handbook, is available from Arrow Tank Co., Inc., 16 Barnett St., Buffalo 15, N.Y. Eight brochures on specific industries and phases of wood tanks also are available.

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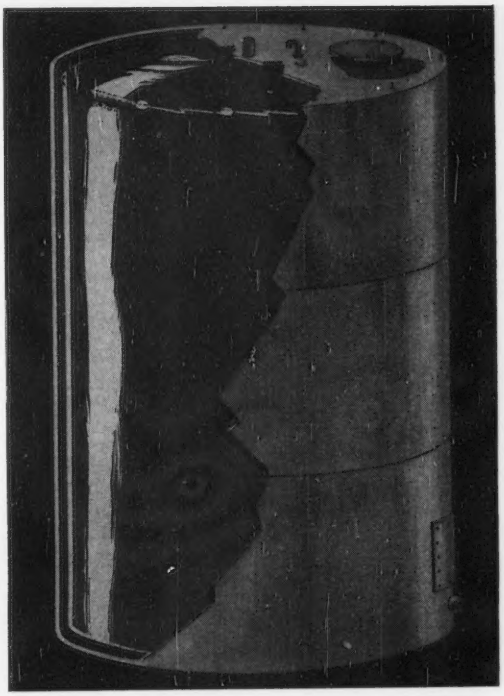

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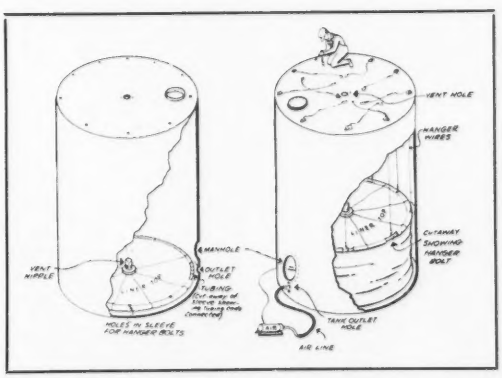

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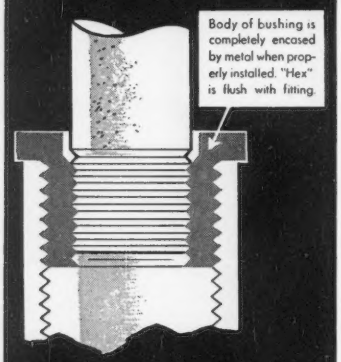

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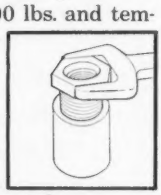

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TABLE 1—Resistance of Woods to Various Chemical Solutions
Condition of Woods After 31 Days Immersion in Cold Solutions*
(Examined after 7 days drying)

	Cypress	Redwood	Yellow Pine	Fir
Hydrochloric Acid 5% (HCl)	NAC	SS	SS	NAC
Hydrochloric Acid 10%	NAC	SS	SS	NAC
Hydrochloric Acid 50%	S, WF	S, WF	S, WF	SS, SB, SWF
Sulphuric Acid 1% (H_2SO_4)	SS, SB	NAC	SS	NAC
Sulphuric Acid 5%	SS, SB	SS, SB	SS	SS
Sulphuric Acid 10%	S, FSD	S, FSD	S, FSD	S, FSD
Sulphuric Acid 25%	SSp, FSD	SSp, FSD	SSp, FSD	SSp, FSD
Caustic Soda 5% (NaOH)	SSp, FSD	SSp, FSD	SS, FSD	S, NAC
Caustic Soda 10%	S, SB, FSD	SS, SB, FSD	SS, SB, FSD	S, FSD
Alum 13%	NAC	NAC	NAC	NAC
Sod. Carbonate 10% (Na_2CO_3)	SB, GC	SB, GC	SB, GC	SB, GC
Calcium Chloride 25% ($CaCl_2$)	NAC	NAC	NAC	NAC
Common Salt 25% (NaCl)	NAC	SB, GC	SS, GC	NAC
Water (H_2O)	NAC	NAC	NAC	NAC
Sodium Sulphide (Na_2S)	FSD	SB	SB	SS, SB

Condition of Woods After 8 Hours Boiling in Solutions*
(Examined after 7 days drying)

Hydrochloric Acid 10% (HCl)	FSD	FSD	FSD	SB, S
Hydrochloric Acid 50%	FD, Ch B, S, NG	FD, Ch B, S, NG	FD, Ch B, S, NG	FD, Ch B, S, NG
Sulphuric Acid 4% (H_2SO_4)	SB, GC	SB, GC	SB, GC	SB, GC
Sulphuric Acid 5%	SB, FSD	SB, GC	SB, GC	SS, GC
Sulphuric Acid 10%	B, FD	SB, FSD	B, Sp, FD, NG	SS, GC
Caustic Soda 5% (NaOH)	SSp	S, GC	GC	SS
Alum 13%	SB, GC	SB, GC	SB, GC	SB, GC
Sod. Carbonate 10% (Na_2CO_3)	SB, GC	GC	GC	SB, GC
Calcium Chloride 25% ($CaCl_2$)	SB, GC	NAC	SB, GC	SB, GC
Common Salt 25% (NaCl)	NAC	SB, GC	SB, GC	NAC
Water (H_2O)	NAC	NAC	SB, GC	NAC

* The table describes the condition of four varieties of woods commonly used for tanks and are based on a report of James K. Stewart, consulting chemist to the Mountain Copper Co., Martinez, Calif. Tests were conducted on samples 1 x 4 x ¼ inch in size, seasoned and chosen so as to be nearly as possible in the same physical condition as the woods would be when used for equipment construction. Results of the tests are described by terms explained in the following key:

Abbreviation Key

B	—Brittle	SB	—Slightly Brittle
Ch	—Charred	Sh	—Shrunk
FD	—Fiber Disintegrated	Sp	—Spongy
FSD	—Fiber Slightly Disintegrated	SS	—Slightly Softer
GC	—Good Condition	SSp	—Slightly Spongy
MSh	—Much Shrunk	SWF	—Slightly Weakened Fiber
NAC	—No Apparent Change	SWp	—Slightly Warped
NG	—No Good	WF	—Weakened Fiber
S	—Softer	Wpd	—Warped

Woods Used–

(Continued From Page 24)

wood at temperatures of 150 to 160 F.

A test was made using California redwood and 25 percent sulfuric acid at 120 F. The solution was violently agitated for 58 hours and then left standing for 336 hours. A KO treated block showed no shredding, no loss of wood fiber, no swelling and only slight softening. An untreated block showed loss of wood fiber and severe shredding.

Of great importance to tank builders and users is the fact that woods so impregnated will swell in contact with water but at a much lower rate. This helps to keep joints tight.

There is a definite trend returning wood to its high position as a versatile, economical material of construction to resist corrosion. Engineers are again specifying heartwood of the four principal tank building woods as well as impregnated woods.

Technical Topics Included in Index

Technical Topics will be included in CORROSION'S annual index. The Topics will be included in the alphabetical subject and author index.

Persons who customarily extract Technical Section pages from each issue for binding are reminded that the Technical Topics pages should be extracted also for a more complete reference to technical informaiton published in CORROSION.

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Aims of T-2 "Minimum Requirement" Activity Explained by Chairman

By W. H. STEWART*

When the present technical committee structure was created in 1954 and the related formation of committee T-2 on Underground Pipe Line Corrosion was accomplished, a ready-made project was waiting this group.

Beginning sometime prior to this reorganization of the technical committees, correspondence from American Standards Association concerning recommendations for underground pipe protection was initiated. ASA had established various standards, or codes, covering physical properties of piping and related structures.

On the problem of corrosion prevention practices, they naturally turned to the National Association of Corrosion Engineers for assistance in this field. As a result of the above mentioned correspondence and subsequent discussions in the technical practices committee, the chore was delegated to T-2 with a rather concise limitations on scope.

In these discussions, where policy and ultimate goals to be attained were aired, it was repeatedly emphasized that "MINIMUM requirements" would be the result and NOT "specifications" or "standards." This policy did not stem from any hasty or ill-chosen desire to avoid the issue. The ASA previously had formulated codes on various physical properties and construction practices on underground gas piping. This, compared to corrosion prevention methods, was a relatively simple task.

Conversely, in the pipe protection field no standards on material and application had been established like those applicable to pipe lines and their fabrication by the American Petroleum Institute and the American Gas Association and other organizations.

It was concluded that NACE should establish "minimum requirements" in this field to form a base on which further design or improvements would doubtlessly be instituted by those concerned with the individual job.

To those familiar with the over-all picture, it is obvious that many good reasons support such a decision.

Geographically, the appropriate requirements vary from almost none in a few isolated areas to extreme severity in others. Numerous methods of coating with various types of materials have been used with some degree of efficacy in different sections of the country. It is obvious, therefore, that no brief, concise "standard specification" that would severely limit the type of material and application could be tolerated or accepted. Since the science of corrosion prevention is not a static art, it would be undesirable to place an inflexible control over its use.

In view of the decisions handed down from NACE's Technical Practices Committee, T-2 committee's efforts were limited to an extremely broad coverage of the subject with an ultimate requirement that could be lived with on a national basis.

The "statement" published in CORROSION in 1956 and amended in October, 1958 reads as follows:

1. Underground steel piping transporting petroleum, gas or related products, where transversing populated areas or existing in such manner as to create a hazard to public safety, should be coated with a protective material of permanent high electrical resistivity. Such coatings, if not so compounded or re-inforced as to resist soil stresses, shall be shielded in such manner as to receive negligible damage from such stresses.
2. Where environment indicates coating, as set out in No. 1, the protective coating should be supplemented by application of adequate cathodic protection of such coated pipe.
3. Where question may arise as to the applicability of these requirements due to existing and long established methods, the problem should be passed to the local electrolysis committee for study and recommendation. It is recommended that such committees be composed of qualified engineers who are cognizant of the over-all problem and are free and capable of making objective decisions.

A study of this statement will reveal that these "requirements" are readily adaptable to almost any condition or environment. Proved practices in various localities that are contrary to those delineated in these "requirements" have been taken into account and provided for.

Some misunderstanding exists outside the T-2 committee concerning "specifications." It should be thoroughly understood that this report or recommendation (Minimum Requirements—) is neither a "standard" nor a "specification." True, some of the completed recommendations contain certain base table or material specifications, but these are considered "minima" and are compiled in such a manner as to include several existing materials of varying divergence in formulation, all to some degree superior to such specification. Any reference to these complete reports, printed or otherwise, as being NACE "specifications" is, to put it mildly, misleading.

To date, "minimum requirements" have been completed on both asphalt and coal tar coating and cathodic protection levels. It is hoped that complete requirements on shields and wrappers will be in final form at an early date. Once these are completed, work on this project will be tendered to TPC for final disposition.

The purpose of this discussion is primarily to inform as many people as possible of the true scope and limitations of this project. By this means doubts in certain quarters as to the aims and final results of this effort should be dispelled. Due to lack of information, rumors and other trivia, the committee has in the past been subjected to pressures from various sources, aimed toward nullifying its efforts. I can assure you that such pressure has been ignored insofar as prosecution of this assignment is concerned.

Once the complete picture, as briefly outlined here, is understood, confused thinking and outright opposition from these few sources should disappear. The need for some basic level in this field exists and must be met. The proper source of such a reference is one that has the "know how" and can formulate a base that can be lived with by the industry. NACE is that source. Rest assured that some organizations, lacking a reliable guide, easily may turn to other sources that could bring about codes extremely difficult, if not impossible to meet.

* Sun Pipe Line Co., Beaumont; Chairman NACE Technical Unit Committee 2 on Pipe Line Corrosion.

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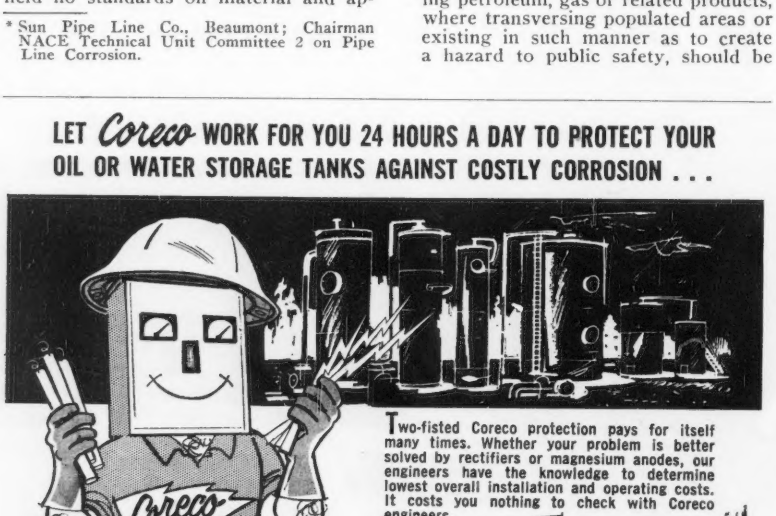

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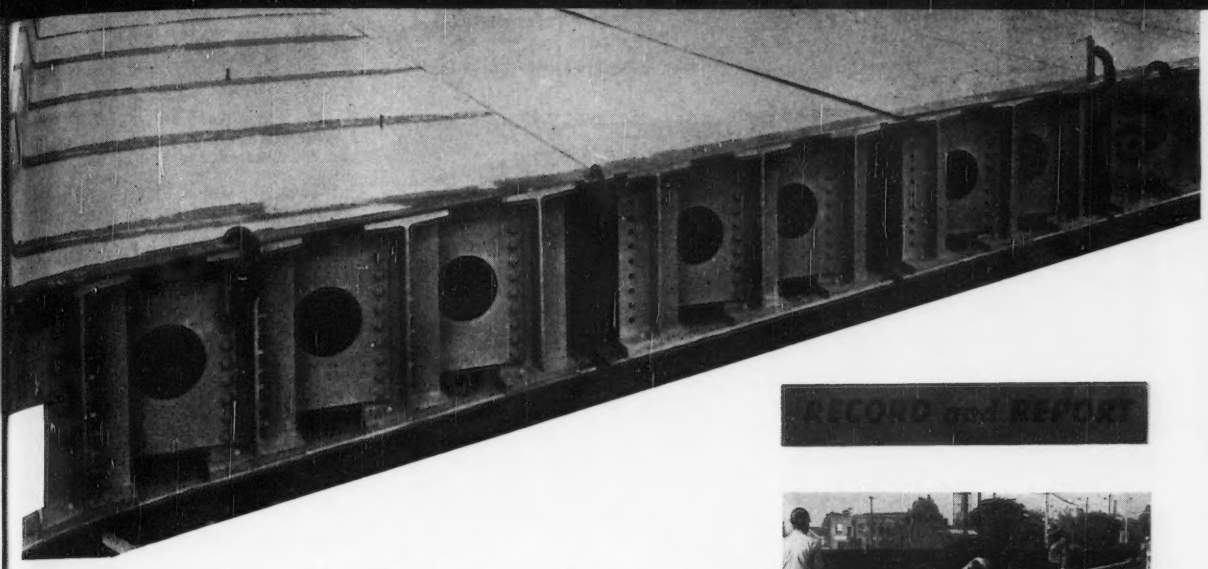


RECORD and REPORT

Wrought Iron Deck Plates Control Brine Corrosion on Rail Bridges

Corrosive brine, coal and drippings from freight cars passing over railroad bridges can cause serious maintenance problems if preventive engineering is not used. Metal deck plates on railroad bridges are buried beneath the ballast on which ties and rails are laid. Thus, the deck plates are almost inaccessible, making proper inspection and maintenance difficult.

Corrosive drippings from freight cars splash onto railroad ballasts, then seep through the ballast to the metal bridge deck. The resulting corrosive attack on floor members often is severe and rapid, requiring new plating to protect or replace badly corroded deck sections. Because the plates are buried beneath the ballast and rails, maintenance work on the plates requires the bridge to be out-of-service for long periods.

Wrought Iron Deck Plates

Corrosion resistant wrought iron is being used for deck plating to reduce severe corrosion of railroad bridges. An example is the deck section shown above. Fabricated with ½-inch wrought iron plate, the bridge unit was shipped to Hawley, Minn., where it was placed over Highway 10 as part of Northern Pacific Railway Company's grade separation program.

This bridge is 46 feet wide and 213 feet long. Wrought iron plates were laid on steel stringers and welded to make the bridge floor water-tight and also to strengthen the structure.

Greater Highway Clearance

This method of construction increases clearance beneath the railroad bridge by minimizing floor depth and reducing amount of fill needed or excavation required under the structure. Railroad engineers are facing a growing need for greater highway clearances for missiles and other large equipment being transported. Minimum clearance on federally approved highways now is 14 feet, but government officials are planning to raise clearance to 16 feet.

Wrought iron also is being used to limit corrosion of railroad bridge drainage systems. Half-round, perforated plates, shown in the middle photograph at the right, are placed under the ballast to drain rain and run-off water which has trickled through perforations in the ballast. This drainage is channeled to sewers beneath the bridge.

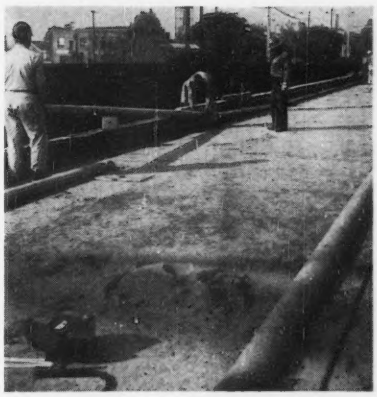
Long Service Life

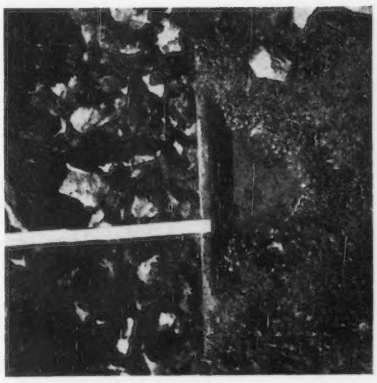
Records on railroad bridge construction show that wrought iron gives long service life and has resistance to brine and repetitive shock and fatigue stresses. In a recent inspection of a wrought iron bridge deck on the Atcheson, Topeka and Santa Fe Railway in Chicago, no severe pitting was found after 24 years of use. The oxide coating which had formed on the metal was adhering tightly. A cold chisel was required to chip this coating.

Another example of wrought iron's long service life under corrosive conditions is shown in the lower right photo. This ½-inch wrought iron plate is subjected to wet ballast and cinders. Installed 21 years ago on the Pennsylvania Railroad's main line over Bladensburgh Road in Washington, D. C., the plate has retained its original thickness despite continuous exposure to the severe corrosive environment.

German Conference in June

"Material Problems in Chemical Techniques" will be the topic for the 1960 meeting of the Dechema Deutsche Gesellschaft fur chemisches Apparatewesen to be held June 14-16 in Frankfort am Main, Germany. Subjects to be included are non-metallic protective coatings, electrolytically deposited metal layers, corrosion inhibitors and laminated construction materials.





DECK SECTION of a railroad bridge (top photograph) was fabricated of wrought iron plates to limit corrosion caused by brine drippings from freight cars. The plates were laid on steel stringers and welded to make the bridge flooring water-tight. Half-round, perforated wrought iron plates (middle photograph) are placed under the bridge ballast to drain rain and run-off water which trickles through perforations in the ballast. Long service life obtainable with wrought iron is illustrated by the ½-inch plate (bottom photograph) which was subjected to wet ballast and cinder corrosion. Installed 21 years ago, the plate has retained its original thickness.

Turn to Page 48 for the
CORRISION ENGINEERING DIRECTORY
If you are providing engineering services for corrosion control, advertising in this directory will be useful to you.

TITANIUM TUBING within a jacket of galvanized steel pipe is used for sodium hypochlorite solution service. The steel pipe conveys cooling water to reduce the temperature of the solution in the titanium tubing. Steel pipe, at lower end of the Y connection, normally would connect with plastic pipe to carry water to another line.

Titanium Tubes Give Good Service With Sodium Hypochlorite

Titanium tubing is being used for heat exchanger and conveyor in handling hot, highly corrosive sodium hypochlorite at the Kuehne Chemical Company, Elizabeth, N. J. After three years' operation, the titanium shows no effects of corrosion.

As a heat exchanger, the titanium tubing runs in a water jacket of larger diameter galvanized steel pipe. The sodium hypochlorite solution enters the tubing at temperatures to 36 C and emerges within one degree of the input cooling water temperature. Feed rate for the solution and cooling water is about six gallons per minute.

The titanium tubing is ⅝-inch OD with 0.028-inch wall thickness. The galvanized steel jacket provides a space of less than ¼-inch between the jacket wall and the titanium tube.

The heat exchanger and conveyor system is composed of 24 lengths of tubing each 30 feet long. Tubes are arranged in three groups of four each, connected in series, and two groups of six each in parallel. Headers are used for cross-over at end of pipe sections.

The tubing used is fabricated from Republic Steel's RS-55 grade, which is designed for resistance to attack in chloride salt solutions, wet chlorine gas and hydrochloric acid concentrations to 5 percent.

The sodium hypochlorite solution has a variety of uses: dye stuffs, shellacs, bleaching agents, oxidizing agents and in organic chemicals. It also is used in medicine and in the textile industry and for water purification.

Corrosion to Be Topic For Gordon Research Conference in July

The Gordon Research Conferences for 1960 will be held from June 13 to September 2. Two of the conferences of possible interest to corrosion engineers will be June 27 to July 1 and July 18-22.

Physical metallurgy and the relation of structure and properties will be the subject of the June 27-July 1 conference to be held at Kimball Union Academy, Meriden, N. H.

Corrosion will be the subject of the July 18-22 conference to be held at Colby Junior College, New London N. H.

These conferences were established to stimulate research in universities, research foundations and industrial laboratories. Informal meetings are held for lectures and discussions, and sufficient time is given to stimulate informal discussions among the members of each conference.

Attendance is by application only. Persons interested in attending should obtain the standard application form by writing W. George Parks, Director, Gordon Research Conferences, Department of Chemistry, University of Rhode Island, Kingston, R. I.

Microthene Samples

Sample quantities of Microthene, a finely powdered polyethylene, are available from U. S. Industrial Chemicals Co., 99 Park Ave., New York 16, N. Y. Powdered polyethylene is used for textile coatings, drum linings and specialized paper coatings. A new plant at Tuscola, Ill., will have a yearly capacity of two million pounds of Microthene.

FOCUS on COATINGS

Five outstanding articles on coatings will be published in the Technical Topics Section of the June issue of CORROSION. A wide variety of coatings topics will be included.

Australian Plant to Produce Vinyl Plastics Being Built

Construction has begun on a $4.5 million plant in Australia to produce Geon vinyl plastic materials. Located at Altona, near Melbourne, the plant will be operated by a new company jointly owned by B. F. Goodrich Chemical Company and C. S. R. Chemicals Limited of Sydney, Australia. Raw materials will be obtained from petrochemical operations carried on by other companies in the area.

"Plastics in Corrosion" To Be Conference Theme

"Plastics in Corrosion" will be the theme of a regional technical conference of the Society of Plastics Engineers, Inc., sponsored by the society's Golden Gate Section. Definite dates in November will be set later. Additional information can be obtained from J. Wilfred Richardson, Rohm & Haas Company, 600 California St., San Francisco 8, Cal.

Alloy Corrosion Paper to Be Given at Metal Congress

"Corrosion of High Temperature Alloys" is one of the technical papers to be presented during the May 9-13 Southwestern Metal Congress and Exposition in Dallas, Texas. This paper by John R. Schley, Haynes-Stellite Co., Kokomo, Ill., is included in the symposium on castings for high temperature and corrosive service.

German Journal Microcards

Microcard editions of three German chemistry journals are available from the Microcard Foundation, 901 26th Street, N.W., Washington 7, D. C. The journals are "Annalen der Chemie," "Chemische Berichte" and "Chemisches Zentralblatt."

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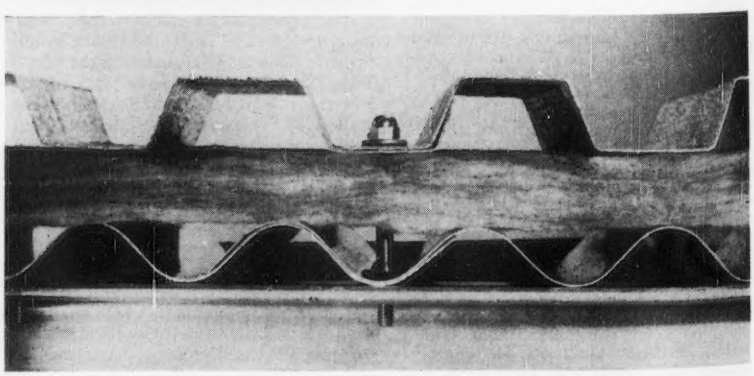
CORROSION's index appears in December.



CURTAIN WALL FASTENERS made of cadmium plated Types 305 and 410 stainless steel to provide maximum corrosion resistance and strength have been designed to cut installation time and costs. Self-tapping screw on one end reduces installation time. The fastener replaces three separate fastening steps used in conventional methods, according to the manufacturer, Fabricated Products Co., West Newton, Pa. The fasteners work in combination with most materials being used in curtain wall construction including stainless or galvanized steel or aluminum sheets. Conventional curtain wall fastening usually requires a bolt, nut and washer combination to fasten the interior sheet to the framing, a spacer bar to hold the insulation and an additional fastener to secure the exterior sheet to the inside sheet.

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BOOK NEWS

The Presentation of Technical Information. By Reginald O. Kasp. 146 pages 5 x 7½ inches, cloth. Second printing, 1959. The Macmillan Company, 60 Fifth Ave., New York 11, N. Y. Per copy $2.50.

The second printing of a book written by an English engineer is an easy-to-read exposition of what every person should know who is occupied with expository writing, especially technical writing. The author's approach is principally along the routes of logic and psychology.

The chapter headings are indicative of the approach: Functional English, functional and imaginative literature compared, the problem of functional English, choice of material, work done by the person addressed, proper pace, what it is about, making it easy to understand, making it easy to remember, circumlocutions, generalizations, on meaning what you say, qualifications, metaphors and words.

There is a useful subject index.

Symposium on Electroless Nickel Plating. 67 pages, 6 x 9, cloth. November, 1959. ASTM Special Technical Publication No. 265. American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa. Per copy, $2.50.

The nine papers comprising the collection were developed into a symposium by Section C, Subcommittee I under Committee B-8 on Electrodeposited Metallic Coatings. Subjects covered are history, chemical reactions, characteristics of deposits, processing procedures, advantages and limitations, applications, test methods, patents and references.

Marine Corrosion Handbook. By T. Howard Rogers. 297 pages, 5¾ by 8 inches, flexible cloth. January, 1960. McGraw-Hill Book Company, Inc., 330 West 42nd St., New York 36, N. Y. Per copy, $12.50.

A handbook designed for the use of operating engineers and draughtsmen who are not necessarily conversant with corrosion theory. The author, formerly Corrosion Investigator, British Non-Ferrous Metals Research Association, and now Officer-in-Charge, Naval Research Dockyard, Laboratory, Halifax, notes in a preface six principal books of reference of which three were published in England.

The material is arranged in alphabetical order beginning with Admiralty Brass and ending with zinc chromate. In between are hundreds of items, considered briefly in clear prose. There are numerous illustrations and diagrams, a glossary of corrosion terms (none from the NACE Inter Society Corrosion Committee's compilation) and an alphabetical subject index.

The subject matter, designed principally for the information of Canadian Royal Navy personnel, is oriented exclusively toward the salt water marine environment.

Marine Boring and Fouling Organisms. Dixy Lee Ray, Editor. 536 pages, 5½ x 8½, cloth. 1959. University of Washington Press, Seattle 5, Wash. Per copy, $8.50.

Thirty-four papers presented at a symposium in September 1957 at the Friday Harbor Laboratories of the University of Washington, Seattle. The symposium, sponsored by the university's Department of Zoology with the aid of the Biology Branch of the Office of Naval Research was supported by 20 companies and organizations concerned with the depredations of marine animals and their control.

The papers are grouped under the headings: Limnoria, Terediniens and Barnacles, considering their ecology and distribution. A section headed "Cellulases" deals with the characteristics of cellulose materials used as food by these organisms and the kinds of microbiological and macrobiological organisms that attack it, as well as insects, enzymes and like substances.

The section on economics considers treating practice, evaluation of posions and other data concerning the protection of wood from biological attack.

There are numerous photographs, graphed data and extensive tables, but no subject index.

PERIODICALS

Decennial Index. Texas Engineering Experiment Station News. March 1950-December 1959 (Vol 1-10 incl) Integral with December 1959 issue. 14 pages. Texas Engineering Experiment Station, Texas A&M College System, College Station, Texas.

Pipes and Pipelines. Vol. 5, No. 1, January, 1960. 56 pages and cover. (Includes "Pipeline Engineering") 97 Old Brompton Rd., South Kensington, London, S.W.7, England. 12 issues, $7.

A magazine devoted to all aspects of pipes and pipelines and ancillary equipment. An editorial estimates annual current production of tubular goods, pipe footing and valves in the United Kingdom at 18 million pounds sterling (about $46 millions).

The January 1960 issue includes articles on rubber hose, recent overseas installation contracts, The Scottish Gas Grid, Testing the Llandarcy-Angle Bay Pipeline and others.

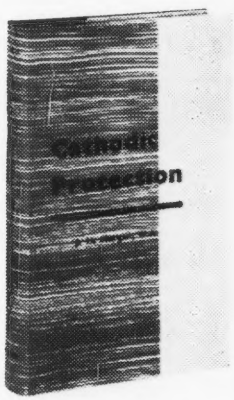
●

NACE's 17th Annual Conference and 1961 Corrosion Show will be March 13-17, 1961, at the Hotel Statler in Buffalo, New York.

Deadline Set for Replacement of Damaged Copies

A disclaimer of responsibility to replace lost or damaged copies of CORROSION has been invoked on instructions of the NACE board of directors. It has been NACE's policy to replace lost or damaged copies at no charge without any limit on the length of time between publication date of the issue and claim for replacement. Henceforth, and effective on June 1, 1960, NACE will replace without cost copies of CORROSION lost or damaged in the mails only if the claim reaches Central Office within 60 days after the date of issuance. With respect to the June, 1960 issue, for example, a claim would have to reach publication offices not later than August 5 to be honored.

is this corrosion necessary?



no! You have an effective weapon against this insidious and costly enemy of metallic structures in the method discussed by J.H. Morgan in

CATHODIC PROTECTION

Its Theory and Practice in the Prevention of Corrosion

325 pages, illus., 1960, $12.00

COMPLETE FREEDOM FROM CORROSION is possible with cathodic protection. This precise, authoritative book explains how in its analysis of the engineering techniques and methods of cathodic protection.

CORROSION COSTS EVERYONE MONEY, so information on its prevention is of vital, timely interest to engineers, metallurgists, architects, manufacturers, designers — in short, to anyone connected with the business of metals.

PROFUSELY ILLUSTRATED, *Cathodic Protection* offers 189 figures and 30 tables. The text covers the field as completely as its table of contents indicates.

CONTENTS:

Foreword — Preface
List of Figures — List of Plates
Electrochemistry, Corrosion and Cathodic Protection
Practical Cathodic Protection Parameters
Resistivity and Electrode Resistance
Sacrificial Anodes
Impressed Current Cathodic Protection
The Cathodic Protection of Buried Structures
Cathodic Protection in Sea Water
The Cathodic Protection of Structures Containing Electrolytes
Stray Current and Interference Corrosion
Instruments for Cathodic Protection
Cathodic Protection Economics
Index

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Key to good design: specify low-cost, trouble-free tubular products of Alcoa Aluminum

The overpowering volume of pipe and tubing needed in the process industries makes it one of the biggest single material investments in most plants. Historically, the repair, maintenance and replacement of piping systems has been too, one of the biggest causes of an alarming increase in maintenance costs. Both factors make vital a clear understanding of the rather remarkable advantages of aluminum pipe and tube.

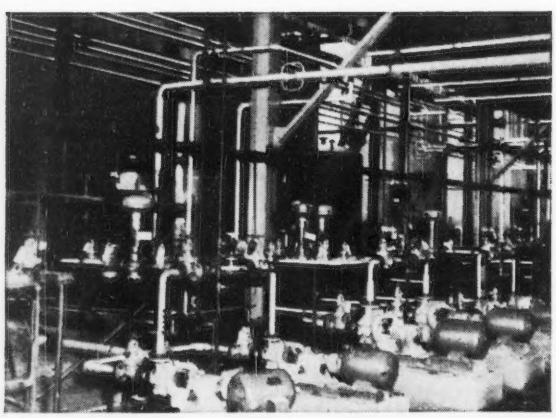
First of all, from a cost standpoint, aluminum is very frequently the lowest cost material suitable for a wide variety of applications in moving fluids through a plant. Consider, for example, the fact that the initial cost of aluminum may often average as much as 50 per cent less than that of admiralty for identical applications. Even greater savings apply when other metals such as stainless or mild steel are compared with aluminum.

Beyond these initial cost savings, aluminum provides significant maintenance benefits. For instance, no other commonly used metal offers aluminum's great resistance to corrosion. And the corrosion resistance for specific alloys exposed to particular environments can be determined from a substantial body of factual service data accumulated by ALCOA over the past 40-odd years.

It is hardly surprising that aluminum, in a variety of tubular forms, is gaining the confidence of more and more designers and builders in the process industries... as suggested by the aluminum applications described on these pages. ALCOA's engineers are anxious and willing to share their factual knowledge of aluminum which inspires this confidence. They are doing so through a series of engineering conferences being held this year in major cities around the country. Your local ALCOA sales office will be happy to furnish details.

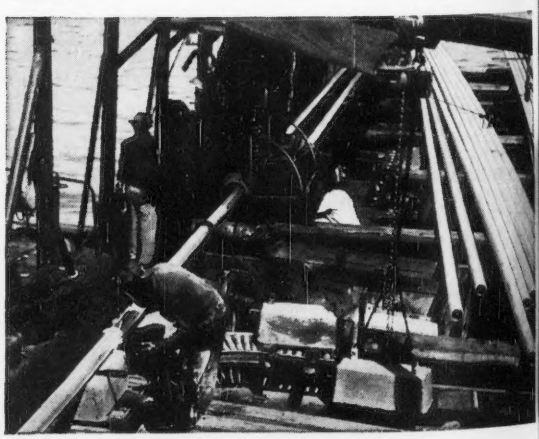
You may also wish to avail yourself of the body of ALCOA literature which describes in technical detail the known performance characteristics of aluminum in a variety of process industries applications. Simply fill in and mail the coupon opposite.

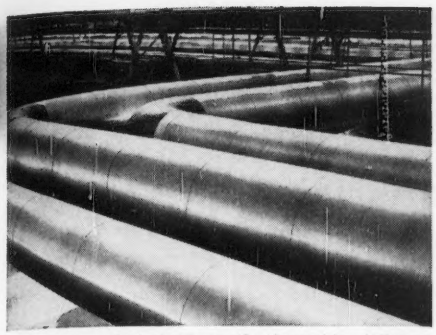
World wide sales through ALCOA INTERNATIONAL, INC., 230 Park Avenue, New York 17, N.Y.



Process piping of Alcoa Aluminum is shown here in a system designed to handle liquid sugar. The natural corrosion resistance of aluminum prevents contamination of the syrup, insures long service life and prevents excessive maintenance. Its scavenging action reduces undesired heavy metal contamination, thereby improving the end product. And aluminum's low friction factor permits fast flow without excessive pumping costs.

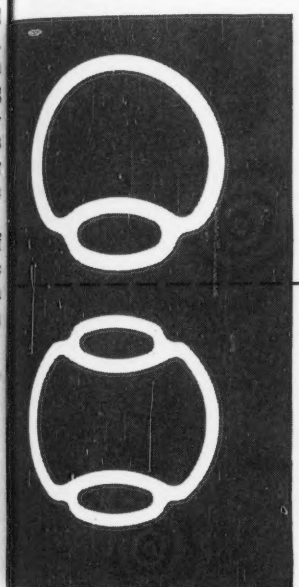
This aluminum pipeline is shown being welded and laid in Lake Maracaibo, Venezuela. Aluminum—without special coatings—has proved highly suitable for this operation because it resists so well the corrosive attack of the brackish waters in the lake. Since no coating is required, the low initial cost of the aluminum has proved a significant benefit. The light weight of the aluminum pipe speeded laying operations, and it has no vulnerable coating which would require babying the pipe.





Alcoa Aluminum jacketing keeps the thermal insulation on these large diameter steam lines fully effective. The light, bright aluminum jacketing shields over 5½ miles of piping and insulation from rain, snow, dirt and ice while providing effective protection against a highly corrosive industrial-marine atmosphere.

New UNISTRENGTH pipe by Alcoa now makes it possible to design low-cost welded aluminum lines with uniform bending, bursting and tensile strength throughout their length. The secret is a reduction in wall thickness everywhere but at the ends where it is needed to overcome the local reduction in strength caused by the heat of welding. The result is aluminum piping which weighs up to 40% less but provides equivalent design strength.

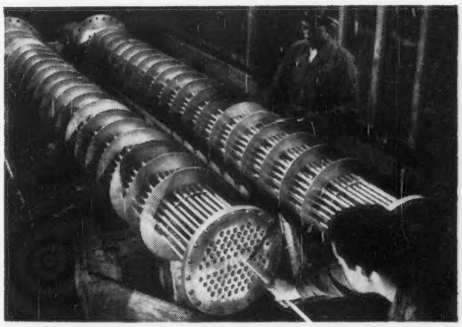


Alcoa UNITRACE is the light, strong, corrosion resistant pipe which provides steam and product passages in a single extruded unit. It has proved an excellent way to cut cost and improve the efficiency of steam traced lines—by eliminating costly external steam jackets or inefficient tracer tubes. Now a new product,

Alcoa DUOTRACE makes possible the same important benefits in steam traced systems where recirculation is desirable. As shown, DUOTRACE provides **two** trace passages plus the product passage in one extruded unit. Flange and Trace Cap fittings compatible with conventional piping are available for both UNITRACE and DUOTRACE.

Design Note: Consider UNITRACE and DUOTRACE as low-cost successors to both heat exchangers and preheaters.

Alcoa Aluminum heat exchanger tubing is frequently the lowest cost material with suitable corrosion resistance for a variety of heat transfer applications. Moreover, aluminum frequently displays significant extra benefits—as in this pair of aluminum oil-to-oil exchanger bundles for preheating vegetable oils. Here, the aluminum alloys have no catalytic effect on the oxidation of the vegetable oil.



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Aluminum Company of America, 875-E Alcoa Building, Pittsburgh 19, Pa.

Please send me the following literature covering Alcoa Aluminum for tubular products and other uses in the process industries:

- ☐ 10197 Aluminum Pipe and Fittings
- ☐ 34-10418 Alcoa Unitrace: Combines Piping and Tracing in One Unit
- ☐ 10270 Alcoa Utilitube
- ☐ 10460 Process Industries Applications of Alcoa Aluminum
- ☐ 20849 Resistance of Aluminum Alloys to Weathering and Resistance of Aluminum Alloys to Chemically Contaminated Atmospheres
- ☐ 20265 Have You Tried Aluminum in Your Refinery?
- ☐ 20437 Aluminum Alloy Heat Exchangers in the Process Industries
- ☐ 20272 Aluminum Alloys for Handling High Purity Water
- ☐ 21090 Resistance of Aluminum Alloys to Fresh Waters
- ☐ 10130 Forming Alcoa Aluminum
- ☐ 19416 Brazing Alcoa Aluminum
- ☐ 10415 Welding Alcoa Aluminum
- ☐ 19051 Alcoa Aluminum Handbook

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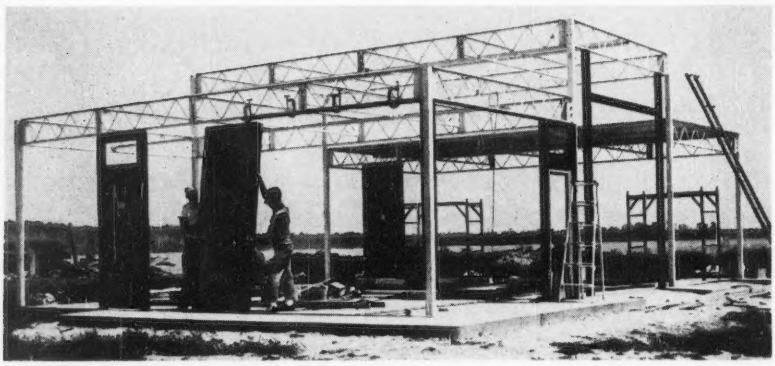

PANELIZED BUILDING SYSTEM used for a gas service station permits rapid construction of a building and complete recovery of parts for re-assemble at another site if necessary. Corrugated aluminum cores with aluminum sheet bonded to the core for light weight and strength were used. The station had 1300 square feet, weighed less than two tons and was completed in only five days. Building panels were tested to withstand windloads to 80 mph.

Panelized Buildings May Solve Need for More School Rooms

Buildings that can be constructed quickly and later dismantled for use at another location with complete recovery of building components may be one answer to America's problem of school classroom facilities.

Modular panelized building systems being produced commercially use a basic panel which is a composite structure combining the function of interior and exterior curtain wall surfaces. These panels act as building blocks and can be adapted for roof and wall sections. Panels have a core of corrugated aluminum for light weight and strength. Exterior surfaces bonded to the core can be varied to specific design requirements of the roof and walls.

In schools, the panelized system could be used to build classroom facilities where expansion is needed quickly. If needed later at another site because of population shifts, the entire structure could be dismantled easily and reassembled at the new site.

Panelized building is relatively simple. After the concrete foundation is poured, the steel frame is erected quickly because steel members are joined by a self-locking system pioneered by Macomber, Inc., Canton, Ohio. Roof and wall panels including pre-hung door and frame packages are put into place and weather sealed by calking along a spline on each panel edge. Extruded aluminum spline molding can be used for external sealing instead of calking.

An example of the panelized building is the service station illustrated above, which was ready for use in five days. Aluminum sheet for the station was supplied by Olin Mathieson Chemical Corporation's Metals Division. Panels were produced by American Metalcore Systems, Inc., Baltimore, Md.

Exterior skins were given a high gloss, weatherable surface by coating with polymethylmethacrylate and fiberglass reinforcement for resistance to color fading. Aluminum sheet coated with an acrylic lacquer also can be used. Tests indicate that acrylic surfaces should have color stability for at least 10 years.

Roof panels were finished with chlorosulfonated polyethylene to obtain a life expectancy of 20 years with good resistance to color fading, weather and ozone.

FOCUS ON CATHODIC PROTECTION

Six articles on various aspects of cathodic protection operation and application will be published in August Technical Topics Section. This focus on cathodic protection is designed to concentrate CORROSION's readers' attention on the subject and emphasize the outstanding performance of the magazine in covering the technical and management aspects of this subject.

The articles to be published are as follows:

Value of Corrosion Protection on Pipe Line Systems—Management's Viewpoint by Harry K. Phipps, Central Pipe Lines Div., Mobil Oil Co., Wichita, Kan.

Suggested Methods and Practices of Cathodic Protection Coordination by David T. Jones, Pacific Telephone and Telegraph Co., Los Angeles.

Ten Years of Cathodic Protection for Large Water Storage Tanks by H. M. Patton, Brown Shoe Co., St. Louis.

Engineering and Design Problems Affecting Cathodic Protection of Lacq Field Well Casings by M. Estavoyer, Societe Nationale des Petroles D'Aquitaine, Paris, France.

Pipe-Type Cables Protected by Shunt Resistor System by H. H. deLaneux and H. A. Medlock, Pacific Gas & Electric Co., Emeryville, Cal.

Novel Distributed Cathode Systems on Telephone Cables by Douglas T. Rosselle, Southern Bell Telephone and Telegraph Co., Atlanta, Ga.

University of Missouri to Offer Three Paint Courses

Three special paint and polymer short courses will be conducted this summer at the University of Missouri School of Mines and Metallurgy, Rolla, Mo.

The first course is titled "Paint Short Course for Beginners" and will be held June 2-17. The second is "Coatings Course for Architects, Painting Contractors and Maintenance Engineers," July 11-15; the third course is "Advanced Paint and Polymer Refresher Seminar," July 18-29.

Additional information and registration blanks can be obtained by writing Wouter Bosch, Missouri School of Mines, Rolla, Mo.

Correct Use of Materials Is Norwegian Exhibit Theme

Correct use of materials at the right time and place will be the theme of a special exhibition to be May 27 to June 3 in Norway. The exhibition is arranged in collaboration with the Norwegian Corrosion Research Federation and the Norwegian Industries Development Association.

Purpose of the exhibition is to point out possible solutions to the corrosion problems by use of new principles, modern methods and products.

Catalog Lists Thousands Of Russian Publications

"Newspapers and Magazines of USSR," a catalog listing several thousand publications issued in the Soviet Union has been received at Central Office NACE. The catalog gives the name of the publications in Russian and English, number of issues per year and the annual subscription rate. Those magazines having tables of contents or annotations in English are indicated.

Sea Horse Meeting

Proposed topics for the annual meeting of the Sea Horse Institute May 31-June 3 at Wrightsville Beach, N. C., include many corrosion problems. Topics include problems related to marine corrosion of metals, cathodic protection and metallic and organic coatings.

Pittsburgh Coke Divisions

Pittsburgh Coke & Chemical Company has reorganized its structure to consist of three subsidiary companies and a single division. They are Pittsburgh Chemical Company, U. S. Concrete Pipe Company, Green Bag Cement Company and the Coke & Iron Division of the main company.

ASHRAE Meeting June 13

The 67th annual meeting of ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.), will be held June 13-15 in Vancouver, B. C.

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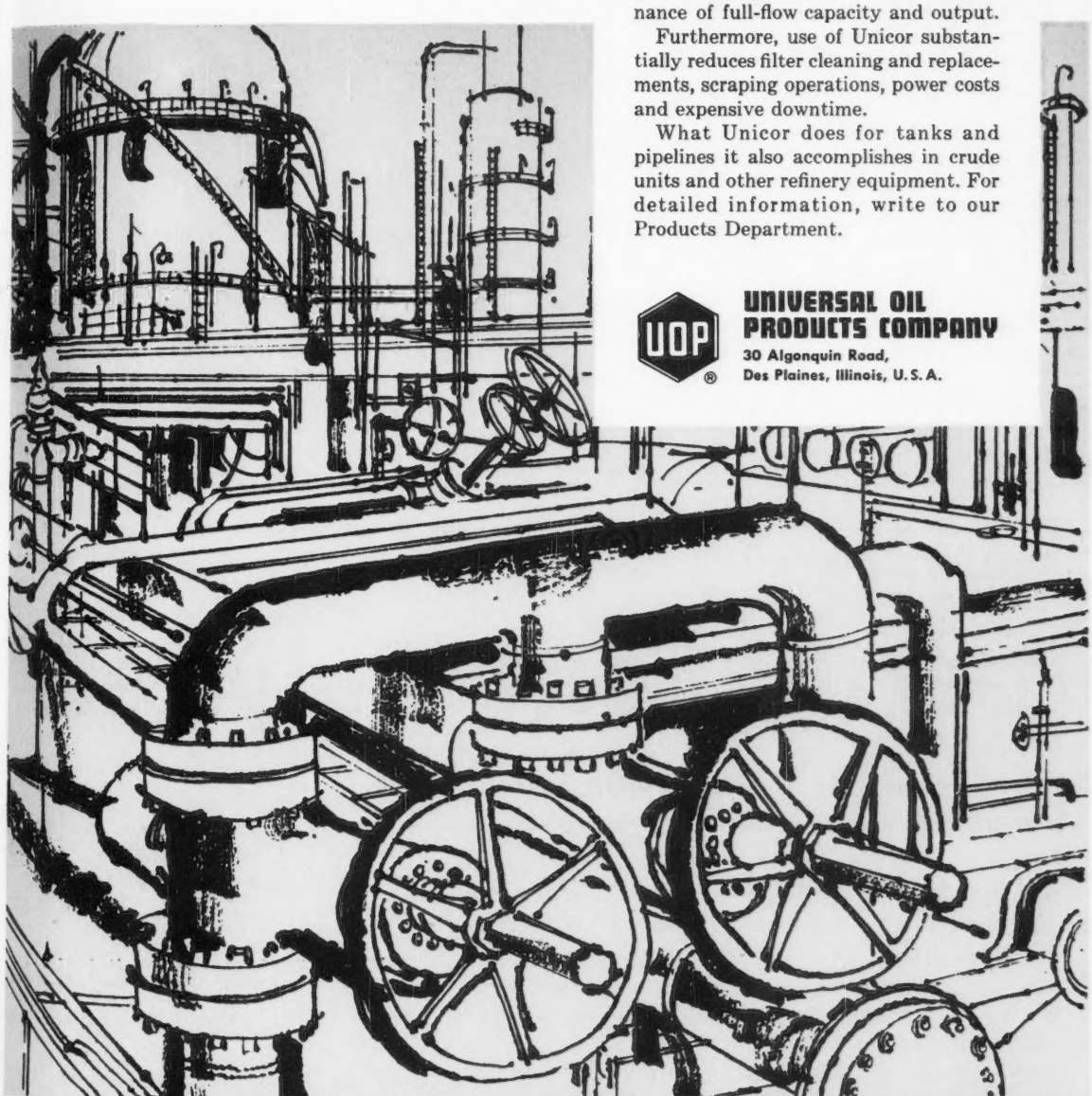
Are you aware of the tremendous difference a small amount of Unicor can make in pipelines and crude units?

This film-forming, oil-soluble inhibitor prevents all kinds of corrosion. Wherever Unicor has plated out on a surface, it gives protection to tanks, vessels and pipelines whether full, part-full or empty.

By adding a small amount of Unicor to your product—10-20 parts to a million—you prevent product contamination, profit-robbing corrosion; assure maintenance of full-flow capacity and output.

Furthermore, use of Unicor substantially reduces filter cleaning and replacements, scraping operations, power costs and expensive downtime.

What Unicor does for tanks and pipelines it also accomplishes in crude units and other refinery equipment. For detailed information, write to our Products Department.



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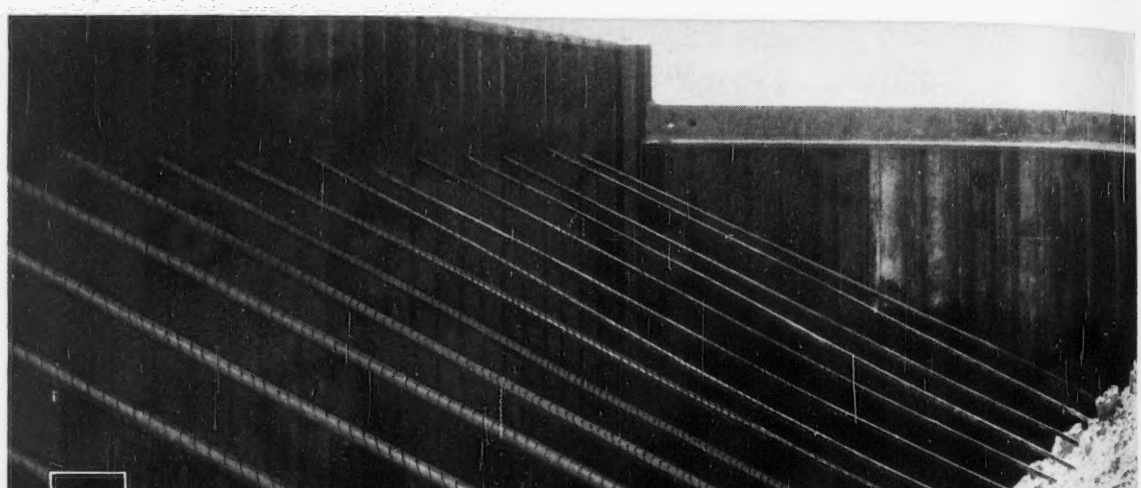

To assure permanent support for this seawall on Lake Michigan, a Wisconsin building contractor wrapped his anchor rods in Polyken tape. Even with an abrasive backfill of wet cinders and ashes, this builder knows Polyken will prevent corrosion and help protect buildings behind the wall.

with permanent Polyken

The durable, doubly thick adhesive of Polyken tape seals all voids—seals out corrosion

Tough, long-lasting Polyken Protective Coatings keep air and moisture from the metal. And abrasion has little effect.

Try Polyken in your plant. Get complete protection for your pipes, conduits, rods—almost anything cylindrical. Polyken is made of an inert polyethylene, with an unplasticized, non-drying film. The unusually high adhesive bonds the coating to clean surfaces without a primer.

Maintenance costs are considerably lower than with paint. Polyken goes on quickly, economically, right from the roll. No heat, no solvents or thinners, no drying or clean-up time. And keep in mind Polyken's lower water vapor transmission rate, higher electrical insulation resistance and better cold-weather handling and durability.

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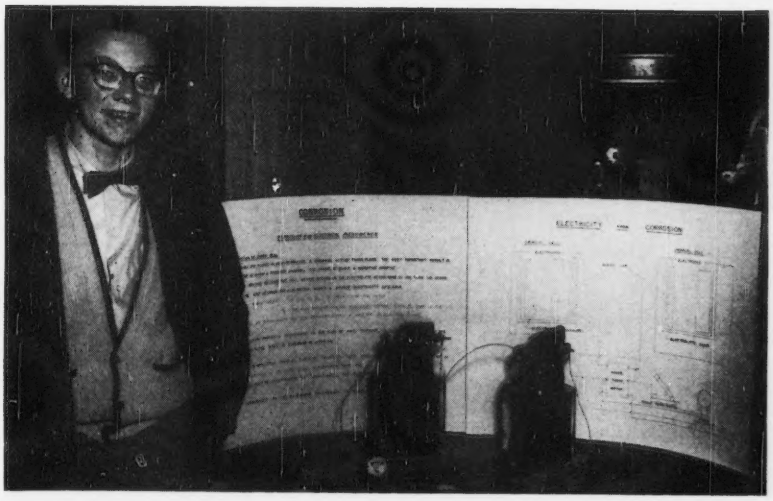

CORROSION EXHIBIT demonstrating the electrical phenomenon of corrosion won third place at the Wyoming State Science Fair at Casper for Charles Engstrom of Kemmerer, Wyoming. The exhibit consisted of electrolytic cells using magnesium and carbon as anodes and salt water as an electrolyte to power a small motor.

Science Fair Exhibit Shows Corrosion's Electrical Phenomena

An exhibit demonstrating that corrosion is an electrical phenomenon won third place at the Wyoming State Science Fair at Casper, Wyoming. The exhibit, prepared by Charles Engstrom, son of Mr. and Mrs. Louis Engstrom, Kemmerer, Wyoming consisted of electrolytic cells using magnesium and carbon as anodes and salt water as an electrolyte.

Young Engstrom's exhibit won honorable mention at his Kemmerer junior high school fair and second place in the Green River (Southwest District) Science Fair. He was interested in preparing an exhibit with this theme after seeing an article in CORROSION concerning a "corrosion motor" which operated by electricity from a corrosion cell.

Rubber Suction Hose Is Reinforced With Spiralled Polyethylene

High density polyethylene is spiralled on a rubber suction hose for reinforcement and to eliminate the possibility of sparks in industrial applications where dust and gas create an explosive atmosphere. Designed to rebound to full diameter when crushed by heavy equipment and to be virtually kink-proof, the hose's core and coil are wrapped with an outside layer of abrasion resistant rubber. The spiral of polyethylene (manufactured by W. R. Grace and Company's Polymer Chemicals Division, Clifton, N. J.) resists action of corrosive chemicals and has high tensile and impact strength. Available in sizes through three inches in diameter with rubber or synthetic tubing, the hose is produced by Goodall Rubber Co., Whitehead Road, Trenton 4, N. J.

June Training Seminars to Be on Use of Polyvariables

Polyvariable experimentation, newly developed methods for experimentation in 10, 20 or more variables, will be discussed in training seminars to be held across the nation during June under sponsorship of the Statistical Engineering Institute. The seminars will be held in Boston, Pittsburgh, Chicago, Los Angeles and Houston. Additional information can be obtained from F. E. Satterthwaite, Institute Director, 8 Fuller Road, Wellesley, Mass.

British Corrosion Show

Corrosion control materials, methods and services will be included in the Corrosion Exhibition 1960 to be held from November 29 to December 2 at Empire Hall, Olympia, London, England. The exhibition is sponsored by "Corrosion Technology," a British magazine.

•

NACE's 17th Annual Conference and 1961 Corrosion Show will be March 13-17, 1961, at the Hotel Statler in Buffalo, New York.

RUBBER SUCTION HOSE reinforced with a spiral of durable high density polyethylene is designed to be kink-proof and to rebound to full diameter when crushed by heavy equipment.

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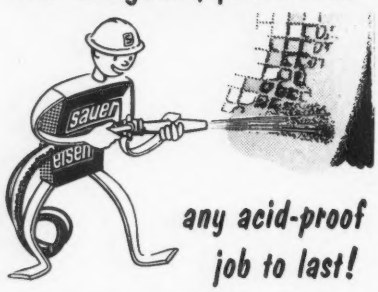

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Ask for Data Sheets.

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J. C. Hudson Is Awarded Hadfield Medal for 1960

J. C. Hudson, head of the Corrosion Section, Chemistry Department, British Iron and Steel Research Association, London, England, has been awarded the Sir Robert Hadfield Medal for 1960. This annual award is made by the Iron and Steel Institute.

Mr. Hudson received NACE's Frank Newman Speller Award at the Dallas Conference in March for his work in the field of corrosion.

Over Million Dollars Given To University Research

More than one million dollars have been awarded to 143 universities and colleges in the Du Pont Company's annual program of aid to education. The program is for fundamental research by universities for strengthening the teaching of science and related sugjects and for educational and research facilities in science and engineering.

Organic Wastes Course

A course on bio-oxidation of organic wastes theory and design will be offered June 20-24 by Manhattan College's Department of Civil Engineering, New York 71, N. Y.

May 12-13 ASM Conference

A Refractory Metals Conference will be held May 12-13 by the Los Angeles Chapter of the American Society for Metals at the Hotel Del Mar.

COAL TAR ENAMEL COATING on 10-foot diameter pipe sections exposed for 20 years to the atmosphere in California was considered in excellent condition by inspectors. Strips cut from the pipe were re-rolled into smaller diameter pipe (shown above). Even after the re-rolling, engineers stated that no re-coating would be necessary before the pipe was put into use.

Coal Tar Coatings Withstand 20 Years Outdoor Exposure

Coal tar enamel coatings applied 20 years ago to the interior of 10-foot diameter pipe sections in Los Angeles, Cal., are still in good condition after being exposed to the sun and wide temperature variations in California's San Fernando Valley.

Early in 1959, the Los Angeles Department of Water and Power had emergency use for 8-foot diameter pipe. Because the 10-foot diameter pipe sections (30 feet long) were in excellent condition, the department decided to cut longitudinal sections from the pipes for reshaping and rewelding into 8-foot diameter pipe. After this reshaping operation, the coal tar coatings were still in excellent condition and required no re-coating.

The 30 by 6 foot sections remaining from the pipe were left in an outdoor scrap pile for almost a year. The department decided these sections were in too good shape to be sold for scrap and had them flattened and re-rolled into usable pipe sections with 9½-foot diameters. This re-rolling was in the transverse direction from the original rolling of the 10-foot diameter pipe.

After the re-rolling, the protective coatings were described as remarkable by NACE member O. N. Denman, materials testing and inspection engineer for the Los Angeles Department of Water and Power. "These re-rolled sections will be placed in storage without re-coating," he said. "When we have need for them, we may have to do some minor retouching of the coatings in places where they have been damaged in handling and cutting. With these minor repairs, the original coatings will continue to be used."

Records of the department show that the coal tar coating was applied late in 1940 under specifications of the American Water Works Association. The enamel was applied by centrifugal casting.

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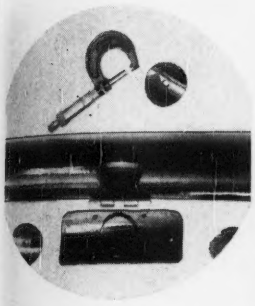

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The illustration shows one of our quality control operators using an inspection instrument in a joint. This instrument permits him to inspect 360 degrees, and his skill and experience in checking thousands of joints makes it possible for him to instantly recognize flaws.

This is only one of the many checks we make to insure good quality. We also make inspection for color, micrometer thickness measurements, Tinsley thickness checks and Tinker and Rasor holiday tests. This close attention to quality throughout the AUTOTRONIC® process is your guarantee of the best possible performance in the finished joint.

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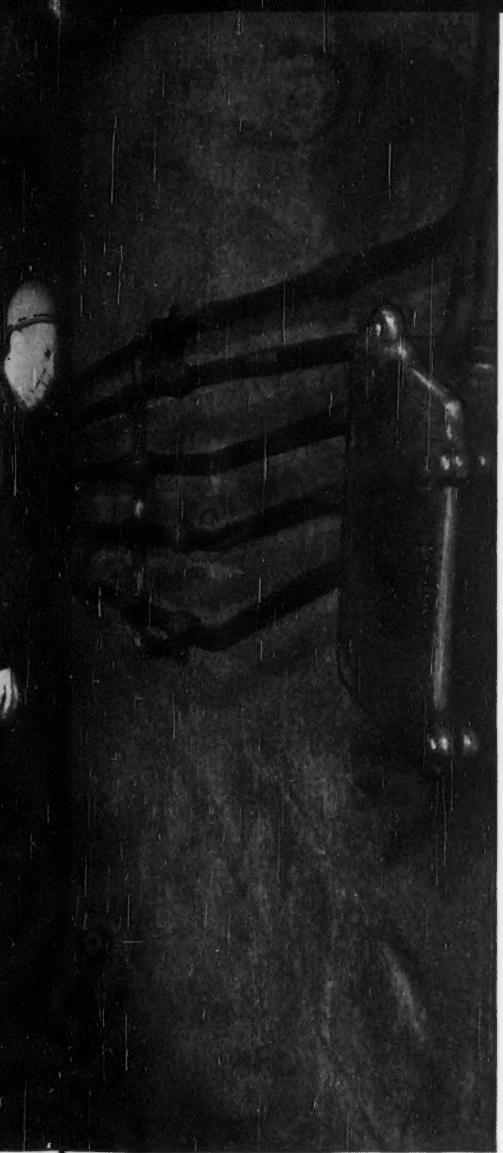

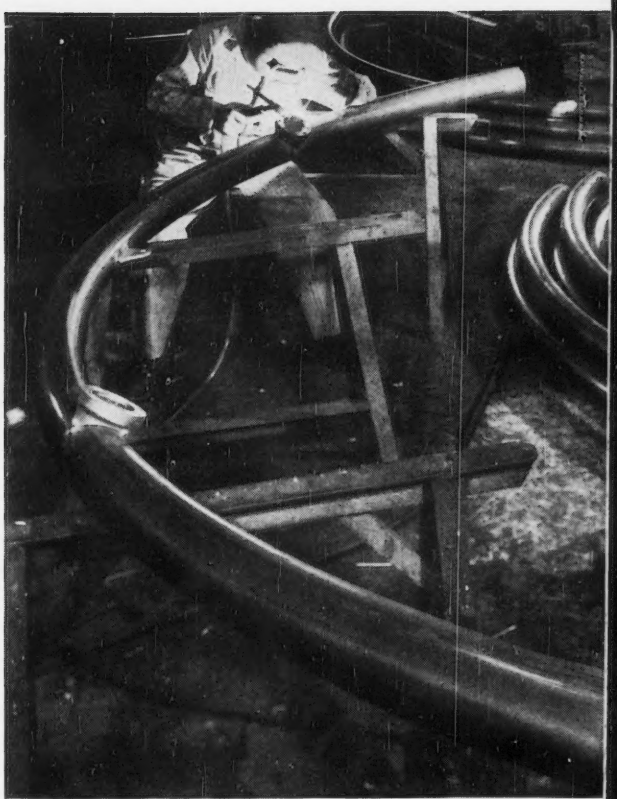

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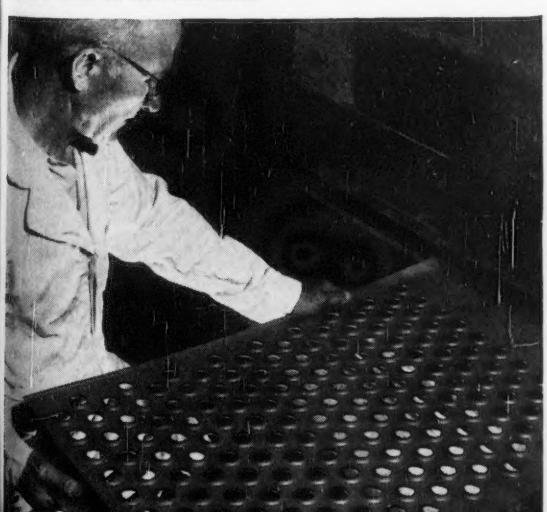

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Cleaners

A variety of soils and contaminants can be removed from precision parts, electronic components, investment castings, bearings, dies, molds and other such items by the Model LGT-40 ultrasonic cleaner, according to the manufacturer, Branson Ultrasonic Corp., 40 Brown House Road, Stamford, Conn. The unit is fully transistorized and designed in a self-contained unit.

•

A dry sulfamic acid product with built-in pH color indicator, corrosion inhibitors and anti-foaming and wetting agents is being produced by the Calgon Company, Box 1346, Pittsburgh 30, Pa. Called Calgon Scale Remover, the product is designed to remove more scale than strong liquid acid. The inhibitors in the acid make it safe to clean systems containing copper, brass, steel, aluminum or galvanizing.

•

Non-toxic, non-inflammable, non-irritating to the skin and absence of residual odor or chemicals are characteristics claimed for Barsad emulsion cleaner, manufactured by R. S. Norris & Associates, 26 Valley Road, Larchmont, N.Y. The cleaner is recommended for cleaning tanks which have contained viscous oils.

Coatings, Organic

A high sheen, rust inhibitive aluminum finish on fences, tanks, standpipes and bus tops can be achieved by use of Totalume, according to the formulator, Wilbur & Williams Co., Inc., 650 Pleasant St., Norwood, Mass. Totalume is formulated specifically to retain a high lustre under severe conditions and is designed to withstand temperatures to 1000 F.

•

Solvent hazards and post-baking, normally associated with epoxies, are eliminated by use of a new epoxy resin pipe coating, according to Minnesota Mining and Manufacturing Co., St. Paul, Minn. Called Skotchkote, the one-part powder resin is claimed to cure in less than 20 seconds with close coating tolerances. It has an adhesion strength of 3000 psi and high impact strength to resist damage from soil or pipe movement and from abrasion and shock of back-filling.

•

Coatings particularly suitable for application on buried or immersed steel and concrete structures are described in a new illustrated booklet available from Allied Chemical Corporation's Plastics and Coal Chemicals Division, Box 75-W, 40 Rector St., New York 6, N. Y.

•

A new quick drying synthetic primer for hot coal-tar enamels has been formulated by Reilly Tar and Chemical Corp., Merchants Bank Bldg., Indianapolis, Ind. Marketed under the name Reilly Redhead, the primer has a translucent red color for visible detection of areas missed in cleaning, not covered by the primer or not covered by the enamel.

•

Designed to protect various resin and latex and sizing application equipment against excessive shut-downs for removal of resin build-up, Water-Skipper, an anti-resin and anti-corroding agent available from Textile Adjuncts Corp., 4907 Farragut Road, Brooklyn 3, N. Y., is resistant to high and low temperatures, high humidity conditions and chemical fumes and vapors. Based on a synergism between polysiloxanes, silicone polymers and methyl tung oil esters, this new agent forms an non-oily, wax-like film when sprayed on metal and other surfaces.

•

A fibrated epoxy mastic that combines rust inhibitive primer properties with resistance to organic and inorganic chemicals is described in Bulletin No. 540A available from Prufcoat Laboratories, Inc., 63 Main St., Cambridge 42, Mass. Called Prufcoat Primastic, the coating is said to make one-coat protection possible for equipment and structures in the chemical, paper, petroleum and marine industries.

Desiccants

To prevent costly freeze-ups and corrosion in gas, liquid or air operated systems, Dehydrators, Inc., Tulsa, Okla., is manufacturing dissipating chemical-type dehydrators which are designed to reduce dew points to —100 F or lower. The units contain a glass fiber filter to trap minute particles suspended in the process stream, a compensating cartridge filled with a chemical compound under constant compression and a water-level gauge. The dehydrators are distributed by Continental-Emsco Co., division of Youngstown Sheet and Tube Co., P. O. Box 359, Dallas 21, Texas.

•

Moisture from the atmosphere is prevented from entering tanks during relief of vacuum caused by product withdrawal or thermal contraction by use of a venting system described in Conservation Bulletin No. 6029, available from Midland Specialties Co., 4801 South on Richmond St., Chicago 32, Ill. Lump anhydrous calcium chloride is used in the system as a dessicant.

Fittings

Fast connections for copper, plastic or aluminum tubing can be achieved by use of Fast-Tite fittings, according to the manufacturer, D & G Plastics Company of Kent, Ohio. Connections are made without the usual clamps and without the necessity of flaring, belling or soldering.

•

Designed to eliminate blow-outs and pull-outs, a new steel fitting for nylon and other plastic tubing has been developed by Flodar Corporation, 16911 St. Clair Ave., Cleveland, Ohio. Known as the Self-Lock Type, the new fitting is recommended for hydraulic and pneumatic power systems, lubrication systems, instrumentation and chemical processing.

Gaskets and Seals

A new fiber reinforced nitrile rubber gasket material made of polytetrafluoroethylene is produced by American Felt Company, 2 Glenville Road, Glenville, Conn. Recommended for its resistance to corrosive gases and liquids under high and low temperature conditions, the material is called Vistex III and is claimed to have 100 percent compression recovery, exceptional tensile strength and non-adhesive properties.

•

Using balanced fluid pressure to replace operational springs, CounterPoise Seals are designed to keep deep carbon faces in contact when pump is shutdown or pressure is reduced below operational level. This method of springless sealing and its use for a wide range of fluids including corrosive ones are described in a brochure available from A. W. Chesterton Company, 6 Ashland St., Everett 49, Mass.

Heat Exchangers

Impervious graphite immersion heat exchangers and circulating steam jets for heating or cooling corrosive solutions in all types of tanks are discussed in a bulletin available from National Carbon Company, Division of Union Carbide Corp., 535 Fifth Ave., New York 17, N. Y. Included are general description, installation and operation information.

•

A mercury inhibited brass condenser and heat exchanger tube alloy has been developed by Bridgeport Brass Co., Bridgeport 2, Conn. The mercury inhibitor is said to form a mercury oxide film which kills bio-organisms and helps form a soft protective scale. The new tube alloy called Alloy 77 is described in a technical data sheet available from Bridgeport Brass.

Inhibitors

A new combustion chemical called Nalco 159 designed to protect residual oil-fired boilers against slag and cold-end corrosion has been developed by Nalco Chemical Co., 6216 West 66th Place, Chicago 38, Ill. According to the manufacturer, Nalco 159 protects boiler fireside surfaces by interrupting high temperature reactions that cause oil ash constituents to form slag.

•

A new chemical product that protects food filled tin cans from rust and corrosion while the cans are pre-cooked in water has been developed by Calgon Company, a division of Hagan Chemicals & Controls, Inc., Hagan Bldg., Pittsburgh 30, Pa. Called Banox Composition WT, the compound is added directly to the cooking water.

•

A bacterial inhibitor used in cutting oils and coolants is available from Elanco

Products Company, a new division of Eli Lilly and Company, 740 S. Alabama St., Indianapolis 6, Ind. Called Elcide 75, it is a thimerosal and sodium o-phenylphenate.

Instruments

A specification guide for electrical holiday detector inspection is available from Tinker & Rasor, manufacturers of electrical testing instruments, P. O. Box 281, San Gabriel, Cal. The guide explains use of a holiday detector and gives recommended points to be included in specifications for electrical inspection of thin film coating, hot applied bituminous or prefabricated protective film coating and coated pipeline or other metal structures after they have been buried in the ground.

•

A new laboratory mixer designed for small, difficult to mix liquid-solid combinations in tiny batches of material in volumes from ½ to 2 ounces has been developed by Atlantic Research Corporation, Alexandria, Va. It is a sealed unit and mixes materials under controlled environments. All parts are precision machined of polished stainless steel.

•

A non-electric instrument for direct and continuous indication of specific gravity in flowing process liquids has been developed by Precision Thermometer and Instrument Co., 1434 Brandywine St., Philadelphia 30, Pa. This Princo Densitrol W-756 has a body of Pyrex for impact resistance and is immune to most corrosive liquids because of Pyrex, tantalum and tetrafluoroethylene used on wetted surfaces, according to the manufacturer.

•

A transistorized pipe valve and cable locator with the single turn transmitting and receiving coil cast in the fiber glass case is marketed by Gardiner Electronics Co., 2545 E. Indian School Road, Phoenix, Ariz. The transmitter and receiver are powered by four flashlight batteries each and give an average life of 1400 hours, according to Gardiner.

•

Non-destructive measuring of crack depths in forgings, castings, steel bars and rods by a new instrument has been developed by Iroquois Tool Supply Co., Box 184, Tonawanda, N. Y. Using an alternating medium-frequency current of low intensity and voltage, the gauge measures the drop in potential against a given section of the surface. With a solid surface conductor, the loss is equal on any portion. With a crack, the drop in potential is greater.

•

A magnetic crack detector capable of detecting sub-surface and surface cracks, flaws and defects in ferro-magnetic metal has been developed by United States Casting Repair Corp., 6432 Edmund St., Philadelphia 35, Pa. Called the Model S-20 Seal-Lock, the detector has located defects in steel bars as deep as ½ inch below the surface, according to the company.

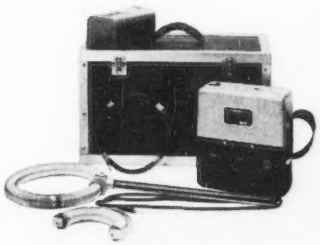
•

A device for accurate measurement of liquid flow through a pipe line from outside the pipe has been developed by Gulton Industries, Inc., 212 Durham Ave., Metuchen, N. J. The Gulton ultrasonic flowmeter uses high intensity sound

(Continued on Page 48)

FOUR WAYS TO INSURE GOOD COATING PROTECTION

Continuity is all important in a protective coating. Whether it's a 90 mil coating on a pipeline or a 3 mil coating on a chemical tank, a tiny pinhole can lead to the destruction of the coating. Use of a Tinker and Rasor Holiday Detector will quickly locate pinholes as well as weak spots caused by air bubbles, coke, rust or scale. Minutes spent inspecting with a Tinker and Rasor Holiday Detector while the job is open can save days of down time later on.



Pipeline Detectors

E-P For damp or dry surface, high electrical resistance coatings. Output adjustable from 8000 to 20,000 pulsating voltage. Electrodes available: half circle, spring for pipe to 6", full circle to 30" silicone brush for flat surfaces.

E-4 This lower cost type of detector is specifically designed for smaller diameter pipe and flat surfaces with dry surface, high electrical resistance coatings. Output adjustable from 8000 to 20,000 D.C. voltage.

Thin Film Detector

M-1 For painted or sprayed thin film coatings. Maximum applied voltage 67½ V., non-destructive to coatings. Belt mounted, 4 lbs. total wt.

Underground Pipeline Detector

P-D For detecting holidays, electrical contacts or locating the pipeline itself, **without uncovering the pipeline.** Completely transistorized—long life and light weight.

Engineering Note:

Every protective coating specification should include TR Holiday Detector inspection. Write for specification guide.

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NEW PRODUCTS

(Continued From Page 47)

waves transmitted through the walls of the pipe to the flowing liquid to measure quantity and rate of flow.

Insulation

A bulletin describing the various properties of Havelex (formerly G. E. Mycalex), a rigid inorganic insulating material, is available from the Taunton Division of Haveg Industries, Inc., 336 Weir St., Taunton, Mass. Havelex is composed of special glass reinforced with mica.

•

Two new types of insulation have been developed by Union Asbestos & Rubber Company, Fibrous Products Division, 1111 W. Perry St., Bloomington, Ill. Insutape, a wrap-on asbestos insulation claimed to be flameproof and weatherproof, is designed for industrial applications requiring an easily applied insulating material under close-clearance conditions and for bent or curved instrument lines and pipe. Unarco U-200, a light weight, rigid, urethane-foam pipe insulation, is designed for use at temperatures from —300 F to 220 F.

Metals, Exotic

Superior Tube Company of Norristown, Pa., has been appointed agent in this country for the sale of pure beryllium tubing produced by the Chesterfield Tube Co., Chesterfield, England. Available in sizes from 0.250 to 2.0 inches, the beryllium tubing is produced from sintered billets by the hot extrusion method. Bore-sized tubing with closer internal tolerances is produced in a limited size range.

•

A new data sheet on holmium metal, one of the more available mono-atomic elements, has been published by Nuclear Corporation of America's Research Chemicals Division, 170 West Providencia St., Burbank, Cal. Holmium has a high magnetic moment and is relatively corrosion resistant.

•

A molybdenum mill products specifications booklet is available from the Refractomet Division of Universal-Cyclops Steel Corp., Bridgeville, Pa. The booklet covers unalloyed molybdenum and Mo-0.5 Ti alloy billets, bars, plates and sheets. Material specifications for each of these products include scope, manufacture, chemical composition, structure, mechanical properties, dimensions, finish, inspection and other information.

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Metals, Ferrous

Engineering properties and applications of heat and corrosion resistant castings are discussed in a 64-page booklet available from International Nickel Company, Inc., 67 Wall St., New York 5, N. Y. It is designed for persons interested in stainless steel and high-alloy casting selection, design and production. The booklet is divided into three sections: heat-resistant alloys, corrosion resistant alloys and fabrication data.

•

A new family of high strength, fine grained, semi-killed mild carbon steels is the GLX-W steels. They are treated with varying amounts of columbium which does not affect ductility. Because of their low carbon content, these steels are easily weldable and have outstanding forming qualities, according to National Steel Corp., Grant Bldg., Pittsburgh 19, Pa.

•

Latest revision of the list of standard designations and chemical composition ranges for heat and corrosion resistant cast alloys has been issued by the Alloy Casting Institute, 1001 Franklin Ave., Garden City, N. Y. New additions to the list of 32 grades of cast alloys are two corrosion resistant alloys designated CD-4MCu and CG-8M.

Plastics

Filled Teflon piston rings, marketed by Garlock Packing Co., 444 Main St., Palmyra, N. Y., are recommended for non-lubricated service to seal reciprocating, oscillating and rotary motion of external and internal cylindrical surfaces against the leakage of liquids or gases. The rings are made from specially processed carbon-filled Teflon which exhibits a lower coefficient of friction than other solid materials.

•

Elastomer components for electronic, missile and automotive applications that exhibit excellent dielectric properties, resist high temperatures and are corrosion resistant have been developed by Vernay Laboratories Inc., Yellow Springs, Ohio. Processing Kel-F brand halofluorocarbon elastomer 3700 with a special peroxide cure, the temperature performance range has been increased from 85 C to 200 C without reducing resistance qualities, according to Vernay. Applications for the elastomer include high temperature electric insulation, hose seals, diaphragms, fuel cells and systems using fuming nitric acids and other corrosive media.

•

Thin and standard wall tubing made of tetrafluoroethylene can be mechanically expanded, then heated to recover original dimensions to clamp tightly over the inserted object is available from Pennsylvania Fluorocarbon Co., Inc., 1115 N. 38th St., Philadelphia 4, Pa. Available in 11 basic colors, the tubing can be used for encasing irregular shapes, protecting electrical components and for joining chemical tubes and metal fittings.

•

Tetrafluoroethylene fluorocarbon resin tubes to prevent erosion and dew point corrosion at the tube sheet opening of heat exchangers and condensers are being supplied by Resistoflex Corporation,

(Continued on Page 50)

2 TOUGH PIPELINE PROTECTORS

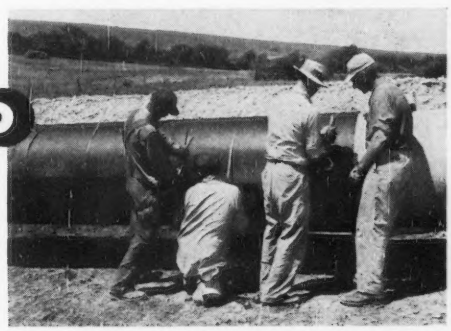
RUBEROID

ASBESTOS PIPELINE FELT...

Adheres to the pipe coating or enamel. Protects pipeline against root attack, soil distortion, and trench settlement which can occur from undergrowth in clay or rocky areas or where the soil is alternately wet and dry. Economical and long-lasting Ruberoid Pipeline Felt meets and exceeds the specifications of the American Waterworks Association and the National Association of Corrosion Engineers.

RUBEROID

FLEXIBLE ROCK SHIELD...



A durable pipeline protector. Guards pipelines in rocky and swampy areas, and at river, railroad and highway crossings. Also used to make tough saddle pads for river weights or hold-down anchors. Can be applied either in two pieces or by the cigarette wrap method. ½″ or ¾″ steel strapping with aluminum seals or use of filament tapes insures permanent placement of the shield. Saves time and effort. Light weight cuts freight cost.

For specification details and samples, write The RUBEROID Co., Industrial Products Division, 500 Fifth Ave., New York 36, N. Y.

The RUBEROID Co.®

PIPELINE PROTECTIVE COVERINGS THAT LAST

NEW PRODUCTS

(Continued From Page 49)

Roseland, N. J. Tapered at the end to reduce turbulence, the tubes can be installed by a hand press fit.

•

A giant chemical fume scrubber made of Hetron 92, a fiberglass reinforced polyester plastic produced by Durez Plastics Division of Hooker Chemical Corp., North Tonawanda, N. Y., was designed to handle 42,000 cfm of dust loaded gases. Designed and engineered by Buffalo Forge Air Cleaning Division of Buffalo Forge Co., Buffalo 5, N. Y., the scrubber is designed to handle large volumes of severely corrosive fumes, mists and dusts of fluoride compounds. Main shell of the hydraulic scrubber was fabricated by Du Verre, Inc., of Arcade, N. Y.

•

Adapter plugs for a chemical rotameter are being made of chlorinated polyether thermoplastic by Brooks Rotameter Company, Landsdale, Pa. The rotameter is a primary metering device to indicate and control flow rate.

•

Properties of fiber glass reinforced plastic pipe for chemical corrosion control are given in Bulletin FRP-1 available from Haveg Industries, Inc., Plastics Park, Wilmington 8, Del. The bulletin is designed to help the engineer select and specify correct stock pipe and fittings to meet corrosion control and safety requirements as demanded in many chemical and petrochemical plants.

•

Separation, cracking and splitting even with small bending radii are eliminated in Flexlon hose construction, according to the manufacturer, Manhattan Rubber Division of Raybestos-Manhattan, Inc., Passaic, N. J. Hose construction features a bonding of the tetrafluoroethylene tube to the hose body.

•

Seamless construction and integrally molded flanges were designed into a resin regeneration column fabricated from 4000 Duracor, one of seven basic thermosetting resins used to fabricate special corrosion resistant process equipment. The column, produced by Ceilcote Company, 4832 Ridge Road, Cleveland 9, Ohio, was designed to handle highly corrosive chemicals at 180 F.

•

Fasteners such as bolts and nuts made of vinyl to reduce construction costs are produced by Industrial Plastic Fabricators, Inc., Norwood, Mass. The plastic fasteners can be used for underground applications regardless of soil conditions and are not subject to galvanic or electrolytic action. Fillister, hexagon and flat head bolts are available in any standard size.

•

Home awnings made from rigid Geon vinyl, a product of B. F. Goodrich Chemical Company, are being fabricated by Navaco, Inc., Dallas, Texas. The awnings have slats extruded from rigid vinyl which soften and diffuse sunlight, remain free from rust and corrosion and do not require painting, according to Navaco.

Pumps

A hand pump for use on carboys, drums and tanks has been fabricated from Nalgene, Type H (linear, low pressure, high density) polyethylene for chemical resistance and rigidity by Nalge Co., Inc., 75 Panorama Creek Drive, Rochester 2, N. Y. The pump is designed for use of most liquids.

•

Because of the submerged liquid end, a mersemetric pump designed by the Milton Roy Company, 1300 E. Mermaid Lane, Philadelphia 18, Pa., requires no other openings in the tank except the one at the top. Controlled volume metering against pressures to 1200 psi and corrosion resistance are claimed by the manufacturer for this pumping system.

Tapes

Molding tape has been designed for conformable, permanent filling material before overwrapping with any standard pipe wrapping tapes. Called M-45 molding tape, it is manufactured by West American Rubber Co., 410 North Ave., Los Angeles, Cal. Typical applications include filling of shoulders underneath pipe caps, reducing the sharp angle of pipe joints and tees and smoothing rough edges of pipe elbows and valves.

•

A new polyvinyl chloride pressure sensitive pipe protection tape that can be applied at temperatures as low as —5 F has been developed by Minnesota Mining and Manufacturing Company, St. Paul 6, Minn. Called Scotchrap Tape No. 40, it is designed for conformability over a broad temperature range for pipe corrosion protection.

Valves

Stainless steel bleeder valves to permit visual check of bleeding or purging of hydraulic lines while the pump or system is in operation have been designed by Fluid Regulators Corporation, 313 Gillette St., Painesville, Ohio. The valves can be used with any high pressure hydraulic system, according to the manufacturer.

•

An air-hydraulic operating mechanism is one new feature on the Massco-Grigsby pinch valves manufactured by Mine & Smelter Supply Co., 3800 Race St., Denver, Colo. Other new operating mechanisms include a torque arm reducer for manual operation. A new motorized unit provides remote control when the valve is in inaccessible places.

COKE BREEZE

Backfill for Anodes

Ideally suited for use with anodes. Has a high carbon content and comes in sizes of ⅛-inch x 0 to ⅝ x ⅛ inch. In bulk or sacks. Prices on other sizes on reques?.

National Carbon Anodes
Magnesium Anodes
Good-All Rectifiers

WHOLESALE COKE COMPANY

PHONE GARDENDALE, ALA.
HEmlock 6-3603

P. O. Box 94 Mt. Olive, Ala.

MEN in the NEWS

W. A. Balendonck has been named district manager of the Dallas, Texas, office of Neptune Meter Co., 19 West 50th St., New York 20, N. Y.

•

A. F. Beale, Jr., an NACE member, has been appointed director of research for Dowell Division of Dow Chemical, Tulsa, Okla.

•

Bernard Berkeley has been promoted to director of the product development department for Foster D. Snell, Inc., 29 West 15th St., New York 11, N. Y., a chemical engineering firm.

•

J. Calvin Brantley has been appointed director of research for Union Carbide Nuclear Company, division of Union Carbide Corp., at 30 East 42nd St., New York 17, N. Y.

•

Herman Blumenthal has joined Chromalloy Corporation, 452 Tarrytown Road, White Plains, N. Y., as research director of the Chromalloy Division.

•

Union Carbide Plastic Company, division of Union Carbide Corp., 420 Lexington Ave., New York 17, N. Y., has made the following personnel appointments: **Herbert R. Clark** is technical service specialist at Bound Brook, N. J., **Richard G. Hess** will handle flexible packaging, bonding and laminating sales for upper New York state area, **Howard L. McCurdy** is technical sales representative for the South Atlantic Regional Office at Moorestown, N. J., **Charles W. Naylor** is sales trainee in the Midwestern Regional Office at Chicago, and **Douglas L. Peterson** is technical representative trainee at the North Central Regional Office in Cleveland, Ohio.

•

Two new sales engineers added to the Nowery J. Smith Company staff, Houston, Texas, are **Isham L. Harrison** and **Ralph B. Cushman, Jr.**

•

Fredrick C. Disque, Jr., has been promoted to director of research at Alpha Metals, Inc., 56 Water St., Jersey City 4, N. Y.

•

NACE member **Frank W. Davis** has been appointed technical consultant at Southwest Research Institute, 8500 Culebra Road, San Antonio, Texas.

•

John G. Galloway, an NACE member, will be in charge of consolidated sales operations in the middle Atlantic states for the Ceilcote Company, 4832 Ridge Road, Cleveland 9, Ohio.

•

Lt. General James M. Gavin, US Army retired, has been elected president of Arthur D. Little, Inc., Cambridge 40, Mass., an industrial research company.

•

Richard Henderson has been appointed chief engineer for the Arcair Company, P. O. Box 431, Lancaster, Ohio.

•

J. P. Henry has been elected a director and **Henry C. Fechtmeyer** has been named a vice president for Ampco Metal, Inc., 1745 South 38th St., Milwaukee 46, Wis.

(Continued on Page 52)

HOW CAUSTIC SODA IS KEPT IRON-FREE AT 285° F.

You are a producer of caustic soda faced with an unusual corrosion problem in which corrosive damage to equipment is not an important consideration: how can you economically protect your product from iron contamination from the steel tank cars that transport it?

This problem was faced by a leading chemical manufacturer. The solution: an 8-10 mil lining of sprayed HYPALON® synthetic rubber. Result: after more than three years of active service, the caustic soda still is kept iron-free. HYPALON has withstood 50% and 73% caustic soda shipped at temperatures as high as 285° F.—and the HYPALON lining has retained its original smooth finish.

HYPALON, Du Pont's synthetic rubber, is resistant to corrosive chemicals, abrasion, ozone, sunlight, weather, high temperatures (up to 350° F.). All this—plus its flame resistance and permanent colorability—makes it an extremely versatile elastomer.

For more information send for a copy of PROTECTIVE LININGS AND COATINGS, a brochure designed for the engineer with a corrosion problem. For your copy write: E. I. du Pont de Nemours & Co. (Inc.), Elastomer Chemicals Department C-5, Wilmington 98, Delaware.

DU PONT SYNTHETIC RUBBER
NEOPRENE HYPALON® VITON® ADIPRENE®
REG. U.S. PAT. OFF.

Better Things for Better Living . . . *through Chemistry*

EBONY PAINT KILLS RUST

Since 1886

A Refined Coal Tar Base Paint

In all its history of over seventy years, no rust has ever been found under Ebony Paint, no matter how old the job, 30 years and over from a single coat.

So, as long as you see Ebony Paint in place, you can rest assured the metal underneath is getting perfect protection against corrosion.

WRITE FOR BROCHURE

EBONY PAINT MFG. CO.
18th St. and Agnes Ave.
Kansas City 27, Mo.

MEN in the NEWS

(Continued From Page 50)

Fred M. Kinney has joined Good-All Electric Mfg. Company, Ogallala, Neb., as chief engineer of the electrical-mechanical division.

Charles Edward Leyes has been appointed director of building products laboratories of the Sonneborn Chemical and Refining Corp., New York City.

Ralph S. Michael, Jr., has been appointed industrial finishes manager for the paint division of Pittsburgh Plate Glass Co., Pittsburgh, Pa.

Edgar G. Paulson has been named manager of process and waste water engineering for Hall Laboratories, division of Hagan Chemicals & Controls, Inc., Hagan Bldg., Pittsburgh 30, Pa.

B. H. Pickard has been appointed administrative assistant to G. J. Duesterberg, president of Plastic Applicators, Inc., Houston, Texas.

NACE member **Jean-Pierre Polar** has been appointed assistant to the director of technical information for Climax Molybdenum Co., division of American Metal Climax, Inc., 1270 Avenue of the Americas, New York 20, N. Y.

A. C. Polk has been appointed executive vice president and general manager of Dowell Division of the Dow Chemical Co., Tulsa, Okla.

Robert H. Pry has been named manager of the alloy studies section of the General Electric Research Laboratory, Schenectady, N. Y.

E. A. Savinelli has been appointed research director for the Power Chemicals Division of E. F. Drew & Co., Inc., 15 East 26th St., Palmo, N. Y.

Lawrence D. Scharfstein, an NACE member, has been appointed supervisor, corrosion research, for Carpenter Steel Co., Reading, Pa.

Two division managers are retiring from the A. M. Byers Company. They are **Albert D. Sheere** from the Pacific Coast Division and **Walter B. Simpson** from the St. Louis Division.

Mathias P. L. Siebel has been appointed general manager of the newly formed pressure equipment division of the Pall Corporation, 30 Sea Cliff Ave., Glen Cove, N. Y.

NACE member **H. K. Siefers, Jr.,** has been appointed manager of the Engineering Service Department of the A. M. Byers Co., Pittsburgh, Pa.

Charles H. Sommer was elected president of Monsanto Chemical Co., 800 North Lindberg Blvd., St. Louis 66, Mo. **Charles Allen Thomas** was elected chairman of the Board of Directors.

Walter K. Stromquist has been appointed chief of plant systems engineering in the nuclear power engineering department of Alco Products, Inc., Schenectady 5, N. Y.

NACE member **Marcel L. Valois** has been appointed industrial sales representative for the Baton Rouge, La., area by Napko Corporation, Houston, Texas.

Dwight N. Wait has been named general manager of Kemet Company, division of Union Carbide Corp., Cleveland 1, Ohio.

NACE member **Mark Weisberg** and **Harry Kroll** have formed a consulting firm in the field of chemicals and processes. The firm name will be Eltex Research Corporation at 41-45 Seekonk St., Providence, Rhode Island.

Walter H. Wiewel has retired from active service with Crucible Steel Co., Pittsburgh 22, Pa., but will continue his association with the company as a consultant.

APEX

Magnesium Anodes

THE FINAL LINK IN CORROSION CONTROL

Cathodic protection is essential to *maximum* protection against corrosion of underground and underwater pipelines and other metal structures—the indispensable link in *any* chain of protective methods.

APEX anodes are available in 3 lb., 5 lb., 10 lb., 17 lb., 32 lb. and 50 lb. sizes. Prompt service on bare anode with or without wire, or complete packaged anode with wire and back-fill ready for installation.

Send without obligation for our folders detailing the composition, installation, function and dollar-saving performance of Apex magnesium anodes. Our engineers are available for qualified technical consultation.

APEX SMELTING COMPANY

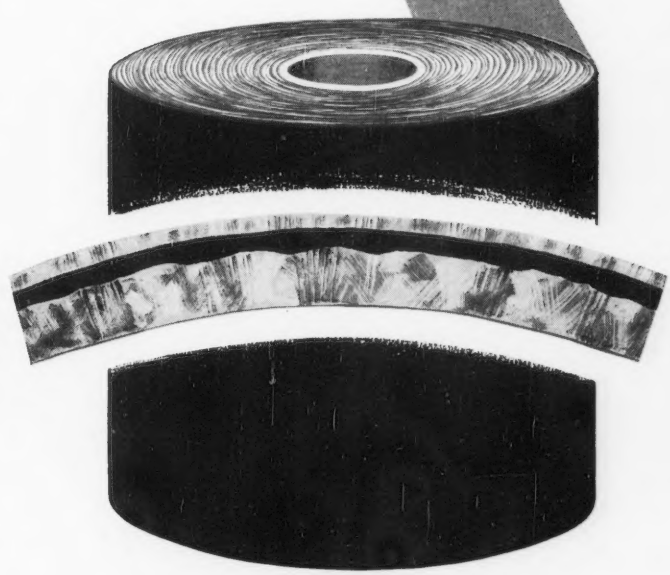
2537 West Taylor Street, Chicago 12, Illinois
Cleveland 5, Ohio • Long Beach 10, California

PLICOFLEX TAPE PROTECTS PIPE

UNDER GROUND

IN THE AIR

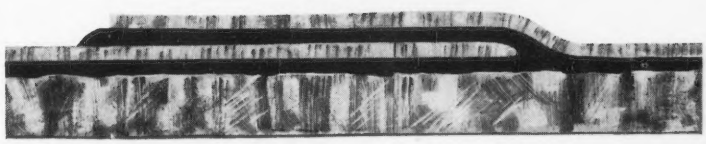
UNDER WATER



Vinyl outer layer
. . . tough, abrasion resistant
. . . non-conductor
. . . fungus and bacteria resistant
. . . waterproof

Butyl Rubber inner layer
. . . gasket-like seals
. . . conformity to surface irregularities
. . . non-conductor
. . . resistant to chemical, fungus and bacteria attack
. . . good bonding
. . . waterproof

Plicoflex primer
. . . superior bond between metal and tape
. . . adheres even under dusty conditions
. . . application unaffected by temperature (weather) extremes
. . . fills in even smallest of surface scratches and pits



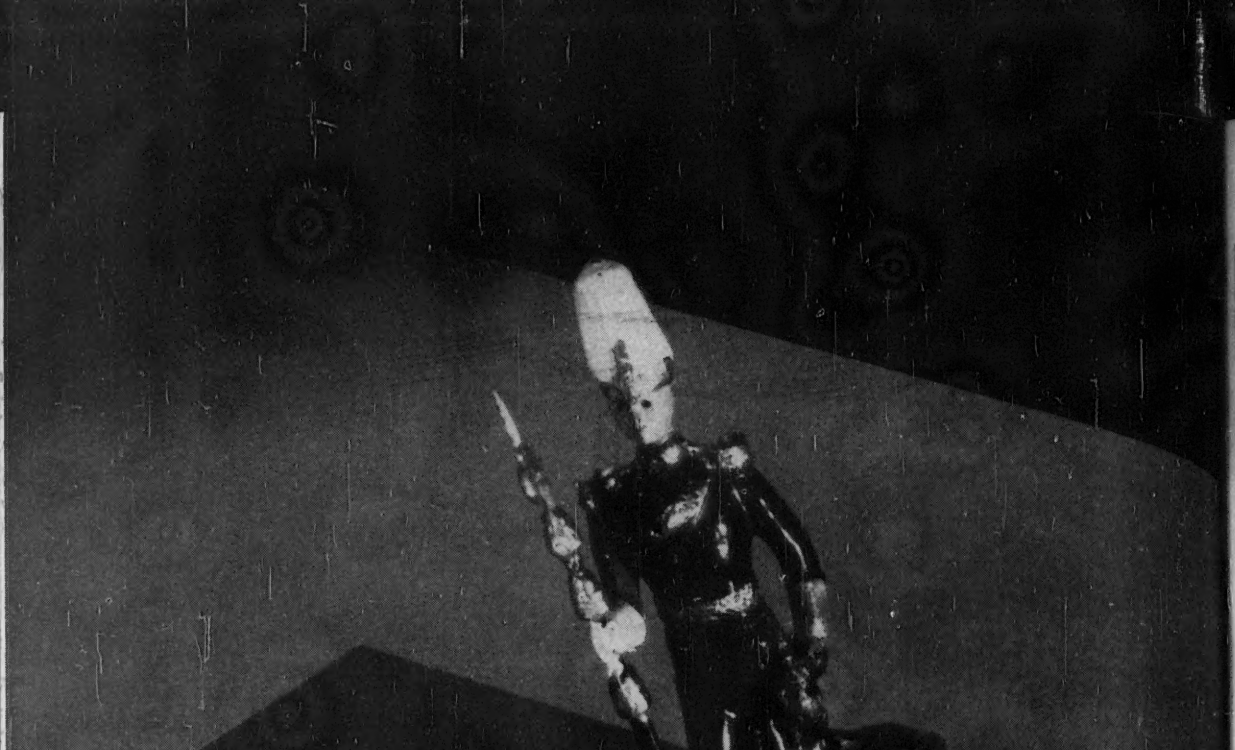
Tension of elastic vinyl compresses the butyl rubber into surface irregularities and makes positive waterproof joints at the overlap of the tape.

Plicoflex pipe wrapping tape is available in widths up to 54", in thicknesses from 15 mils to 35 mils and in 10 standard colors.

PLICOFLEX
TRADE MARK

PLICOFLEX, INC.

2425 Mowery Rd. P. O. Box 45911 Houston 45, Texas
JAckson 6-3711 Teletype HO 277



The coating that heat can't fade away

A Glidden RUSTMASTER H.R. coating was applied to an outdoor hot plate. One year of 900° F. surface temperatures *and* constant exposure to all kinds of weather had no adverse effect on the heat and water resistant film. Unlike the old lead soldier the coating was unharmed.

This unique *outdoor* hot plate test, the only one of its kind, is just an example of the many ways all Glidden coatings are tested and proven.

Glidden Protective Maintenance Coatings are designed and specifically test-proven to match particular requirements wherever protection of chemical, railroad, petroleum, marine and industrial equipment is a problem.

QUALITY Glidden PRODUCTS

COATINGS FOR EVERY PURPOSE

The Glidden Company
INDUSTRIAL PAINT DIVISION
900 Union Commerce Building • Cleveland 14, Ohio
In Canada: The Glidden Company, Ltd., Toronto, Ontario

Write for your free copy of booklet containing complete information on all Glidden Protective Maintenance Coatings.

Process Industry Corrosion Short Course Set

Ohio State Program Registration to Be Limited to 150

A Short Course on Process Industry Corrosion will be held September 12-16 at Ohio State University, Columbus, Ohio. Jointly sponsored by the NACE Technical Group Committee T-5 (Corrosion Problems in the Process Industries) and Ohio State University, the short course registration will be limited to 150 persons.

Registration information and additional details on the course will be published in CORROSION at latter dates.

A schedule of the lectures and their topics are given below.

September 12

Iron and Steel—Wrought Iron, Cast Iron, Ductile Iron, Carbon Steel, Alloy Steel; Heat Treatment; Corrosion Characteristics: R. J. Schmitt, U. S. Steel Corporation.

Stainless Steels—Classes and Characteristics; Alloy Designations; Welding and Heat Treatment; Specifications; Uses; Characteristic Defects: W. G. Renshaw, Allegheny-Ludlum.

Alkaline Environments—Caustic, Ammonia; Ammoniated Organic Compounds; Common Materials of Construction for Processes, Handling; Typical Corrosion Phenomena: Paul Gegner, Columbia-Southern.

Sulfuric Acid Corrosion—Processes; Iron and Steel; Stainless Steels; Copper and Nickel Alloys; Velocity Effects; Handling: W. A. Luce, Duriron Company, Inc.

September 13

Copper and Its Alloys—Classes and Type of Copper; Brasses; Bronzes; Temper Designations; Applications; Corrosion Characteristics: A. W. Tracy, American Brass Company.

Nickel and Its Alloys—Nickel; Monel; Inconel; Other High Nickel Alloys; Applications; Corrosion Characteristics: W. Z. Friend, International Nickel Co., Inc.

Chlorine and Its Compounds—Processes; Handling; Hydrochloric Acid vs Common Materials; Chlorinated Compounds vs Aluminum; L. W. Gleekman, Wyandotte Chemicals Corporation.

Organic Acid Corrosion—Acetic Acid, Formic Acid; Higher Analogues; Copper Alloys; Aluminum; Stainless Steels; Handling and Shipment: J. A. Manning, Celanese Corporation.

September 14

Aluminum and Its Alloys—Types; Designations; Atmospheric Resistance; Corrosion Characteristics: Ellis Verink, Jr., Aluminum Company of America.

Other Non-Ferrous Alloys—Lead; Titanium; Tantalum; Zirconium; Precious Metals; Applications and Characteristics: Walter Boyd, Battelle Memorial Institute.

Other Inorganic Acids—Nitric; Sulfurous; Phosphoric ; Hydrofluoric; Common Materials of Construction; Typical Corrosion Phenomena; Handling: L. R. Honnaker, E. I. du Pont de Nemours Co., Inc.

Corrosion by Water—Seawater; Fresh Water—Recirculated, Once-Through; Common Materials of Construction; Typical Phenomena: W. G. Ashbaugh, Union Carbide Chemicals Company.

September 15

Materials for Low Temperature—Steel and Cast Iron; Alloy Steels; Copper and Nickel Alloys; Stainless Steels; Applications and Specifications: O. A. Hansen, The Linde Company.

Materials for High Temperature—Steel and Alloy Steels; Stainless Steels; Heat Resistant Castings; Other Alloys; High Temperature Oxidation, Corrosion and Related Phenomena: T. M. Krebs, Babcock and Wilcox.

Designing Against Corrosion—Selection, Specification and Design of Alloy Equipment; Concentration Cells; Galvanic Effects; Stress Concentrations; Heat Treatment: W. H. Burton, General Chemicals Company.

Corrosion Testing—Laboratory Tests; Qualification Tests; Accelerated Tests; Elevated Temperature and Pressure Techniques; Field Testing (Insert Racks, Slip-In Racks, Probes, Experimental Installations); Evaluation and Application of Data: M. G. Fontana, Ohio State University.

September 16

Plastic Materials of Construction—Types; Sources; Selection and Specifications; Characteristics; Typical Applications: O. H. Fenner, Monsanto Chemical Company.

Coatings for Chemical Service—Coatings; Linings; Types; Sources; Selection and Specifications; Application and Inspection Criteria; Characteristics: L. S. VanDelinder, Union Carbide Chemicals Company.

Inspection of Metals—Visual; Instrumental; Macro-Etching; Metallurgical Tests; Metallographic Techniques; Examples of Failures: F. A. Prange, Phillips Petroleum Company.

Corrosion in Steam Generating Equipment—Mechanisms; Boiler Corrosion; Condensate Corrosion; Water Treatment; Materials of Construction; Typical Phenomena and Corrective Measures: C. J. Schafer, Betz Laboratories.

Canadian Region

Edmonton Section had 29 members and guests at the March 31 meeting. A. Hanson of Hanson-Parr Consulting Engineers Limited, Edmonton, spoke on the subject "Is Your Corrosion Really Necessary?"

Pierce Is Elected Chairman of ISCC

Robert R. Pierce, manager of the Corrosion Engineering Products Department of Pennsalt Chemicals Corporation, has been elected chairman of the Inter-Society Corrosion Committee (ISCC) sponsored by NACE. He will serve as chairman for a two-year term. He has been vice chairman of the committee.

Pierce

Active in the NACE for many years, Mr. Pierce is past chairman of the Philadelphia Section and was on the NACE Board of Directors from 1955 to 1957. Several of his technical papers on corrosion control work have been published in CORROSION.

The ISCC consists of two delegates from each of 35 U.S. technical, trade and governmental societies and agencies and 13 foreign delegates. Its primary objective is to disseminate corrosion control information to avoid duplicated work. Among its activities is establishment of definitions of terms pertaining to corrosion.

Mr. Pierce is in charge of manufacturing, sales and development for Pennsalt's corrosion resistant mortars, protective coatings, plastic toppings and plastics for fabrication of process equipment. His office is at the company's plant at Natrona, Pa.

Color Slide-Talk on 1960 Corrosion Show

A 35-mm color slide show of about 100 slides of exhibits at the 1960 Corrosion Show at Dallas has been prepared and is available for showing at NACE Section meetings. The show, which has a commentary on specific items exhibited, is available on a first-come, first-served basis on application to G. A. Rolak, NACE Central Office.

The show provides an opportunity for NACE members who were unable to visit the Corrosion Show personally to see some of the equipment on display. While the presentation does not include all the exhibits, it will give a good idea of the show. Presentation time should vary between an hour and an hour and a half.

New Sources Are Added To Corrosion Abstracts

Two new sources of abstracts have been added to the number from which the National Association of Corrosion Engineers derives abstracts for the NACE Punch Card Service and other abstracting activities. These are: RILEM BULLETIN, a periodical published by the International Union of Testing and Research Laboratories for Materials and Structures, 12, Rue Brancion, Paris XV, France; and COBALT, a quarterly periodical published by Centre d'Information du Cobalt, 35 Rue des Colonies, Brussels, Belgium.

Abstracts from RILEM BULLETIN will be identified by the code designation "RIM" and those from COBALT by the designation CB.

The addition of these sources brings to 25 the number of sources which have authorized NACE to use their abstracts.

Northeast Region

Niagara Frontier Section is sponsoring a symposium on organic coatings and their proper use for protection of ferrous surfaces. The symposium will be held May 11-13 at the Hotel Niagara. Program for the 3-day sessions was published on Page 38 of the April issue of CORROSION.

•

Central New York Section heard Henrick Vandroffelaar, division superintendent of metallurgy for du Pont of Canada speak on stainless steel fundamentals at the April 1 meeting.

•

Baltimore-Washington Section scheduled the subject "Corrosion Preventive Measures Necessary in Design and Construction of an Underground Pipeline" for its April 19 meeting.

•

Pittsburgh Section will have a general tour of the National Tube Division Plant for its May 5 meeting.

New section officers for 1960-61 elected at the April 7 meeting are Chairman John B. Vrable, Vice Chairman William L. Mathay, Secretary Raymond C. Bowden and Treasurer John D. Keane.

•

Kanawha Valley Section had a panel discussion on corrosion problems for its March 24 meeting. Panel moderator was C. P. Dillon. Panel members included L. S. VanDelinder, Donald Warren, J. A. Manning and Otto Fenner.

•

Southern New England Section scheduled a plant tour of the Bridgeport Brass Company on April 6 for the final spring meeting. Speaker for the tour was C. Lawrence Bulow, metals engineer with Bridgeport Brass.

•

Northeast Region's 1960 Conference will be October 11-14 at the Prichard Hotel, Huntington, W. Va.

Three Study Levels Covered By Appalachian Short Course

Fifty-four classes and 12 field demonstrations have been planned for the Fifth Annual Appalachian Underground Corrosion Short Course to be held June 1-3 at West Virginia University School of Mines, Morgantown, W. Va.

The 54 classes will cover basic, intermediate and advanced fundamentals of corrosion, public water systems, pipe coatings, instruments and special topics. A complete schedule of the short course is given below.

Educational movies on corrosion and 40 exhibits on corrosion control materials and equipment will be included in the 3-day course.

Schedule for June 1-3 Appalachian Short Course

		10:00 A.M.	AUDITORIUM, REYNOLDS HALL—General Assembly—C. F. Wertz, Speaker							
		12:00 Noon	FIELD HOUSE—Exhibits and Luncheon							
	HOUR	PERIOD	FUNDAMENTALS: Basic	FUNDAMENTALS: Intermediate (Pipe)	FUNDAMENTALS: Intermediate (Cable)	FUNDAMENTALS: Advanced	Public Water Systems	Pipe Coatings	Instruments	Special Topics
WEDNESDAY JUNE 1, 1960	1:30 to 3:00 P.M.	I	B-1 Corrosion Film — C. M. Rutter	IP-1 Corrosion Fundamentals — Col. G. C. Cox	IC-1 Instrumentation — A. L. Ayres	A-1 Advanced Theory — H. V. Fairbanks	W-1 External Corrosion — V. V. Kendall	C-1 Wax Coatings — J. G. Surchek	I-1 Principles of Instruments — H. R. Brownell	S-1 Internal Coatings — N. T. Shideler
	3:15 to 4:45 P.M.	II	B-2 Mud Tub Demonstration — C. A. Erickson	IP-2 Electrochemical Principles — G. J. Powers	IC-2 Corrosion Surveys — E. K. Benson	A-2 Anode Application — F. I. Dorr	W-2 Mud Tub Demonstration — Class B-2	C-2 Coal Tar — O. D. Graff	I-2 Recording Instruments — E. J. Winstel	S-2 Complex Structures — L. G. Sharpe
	6:00 P.M.		FIELD HOUSE — Exhibits				7:30 — Motion Pictures			
THURSDAY JUNE 2, 1960	8:30 to 10:00 A.M.	III	B-3 Stray Current Corrosion — P. Hort	IP-3 Plant Testing — A. W. Peabody	IC-3 & 4 Non-Stray Current Survey Interpretation — R. W. Ackerman	A-3 Cathodic Design — N. P. Peifer	W-3 Cast Iron Pipe — D. W. Johnson	C-3 Asphalts — G. W. Tarver	I-3 & 4 Corrosion Testing Instruments — M. C. Miller	S-3 Storage Wells — W. R. Lambert; G. G. Campbell
	10:15 to 11:45 A.M.	IV	B-4 Bacterial Corrosion — R. E. McVey	IP-4 Stray Current Analysis — W. T. Luttrell		A-4 Construction Practices — L. H. West	W-4 Copper Corrosion — M. E. Flentje	C-4 Coating Tests — L. F. Heverly		S-4 Copper Sulfate Half Cell — T. J. Maitland
	12:00 Noon		FIELD HOUSE — Exhibits and Luncheon							
	1:30 to 3:00 P.M.	V	B-5 Cathodic Theory — H. F. Byrns & W. J. Kretschmer	IP-5 Cathodic Application — D. A. Tefankjian	IC-5 Stray Current Surveys — E. G. Carlson	A-5 Rectifier Units — B. Husock	W-5 Public Systems Corrosion — L. Haynes	C-5 Application Practices — W. R. Curley	I-5 Holiday Detectors — I. E. Davis	S-5 Soil Bacteria — Dr. J. O. Harris
	3:15 to 4:45 P.M.	VI	B-6 Field Practices — F. W. Lloyd	IP-6 Expendable Anodes — E. T. Pearson	IC-6 Mitigative Measures — H. Neugold, Jr.	A-6 Cathodic Facilities Maintenance — G. M. Jeffares	W-6 Transmission Line Corrosion — W. L. LaDue	C-6 Coating Inspectors — J. B. Vrable	I-6 Earth Current Meter — F. E. Costanzo	S-6 Stray Current Bonds & Switches — R. M. Keller
	6:00 P.M.		FIELD HOUSE — Exhibits				7:30 — Round Table Discussion, C. W. Beggs, Moderator			
FRIDAY JUNE 3, 1960	8:30 to 9:45 A.M.	VII	B-7 Control Practices — J. A. Schauers	IP-7 Gas Service Lines — P. P. Skule	IC-7 Bonding & Grounding — D. W. Kissinger	A-7 Interference Current Testing — R. L. Seifert	W-7 Field Practices — W. M. Harris	C-7 Coal Tar Epoxy Coatings — F. Whittier	I-7 Pipe Locators — J. H. Reynolds & E. E. Gross	S-7 Couplings & Corrosion — G. D. Kish
	9:50 to 10:50		DRILL FIELD — Product and Equipment Demonstrations							
	11:00 to 1:00		DRILL FIELD—Corrosion Testing Demonstration, F. E. Costanzo, Chairman							

In acid bath below flange at center, Ni-o-nel alloy heater remains sound — including weld at submerged elbow seam. Plant now specifies Ni-o-nel alloy for all such heaters.

At Pittsburgh Steel Company:

NI-O-NEL alloy solves 15 year problem ...hot sulfuric acid mixtures

The heater this man is looking at warms a violently corrosive bath: 5% sulfuric – 5% nitric acid. Three submerged steam heaters keep the mixture at 150°F. For 15 years, engineers of Pittsburgh Steel Co.'s Thomas Strip Division have tried to build extra life into these heaters. They tried metal after metal, but most lasted only months, causing frequent and costly shutdowns.

But the one heater shown — in service since September, 1958 — was recently pronounced still good as new. It's made of Ni-o-nel* nickel-iron-chromium alloy . . . for corrosive conditions of unusual severity. According to L. J. Crincic, chief engineer at Thomas Strip, "The Ni-o-nel alloy heaters are as good as when they were put in the acid tanks. On the basis of our experience, we plan to go to Ni-o-nel alloy for all heaters on all six lines."

Resists acids, oxidizers . . . "problem" waters, too

Ni-o-nel alloy provides excellent resistance to sulfuric acid in concentrations up to 40% by weight at boiling temperature . . . up to 60% at 80°C. In H_2SO_4 at 280°F., Ni-o-nel alloy parts are outlasting others by 3 to 5 times.

Oxidizing salts other than chlorides usually improve its performance in sulfuric acid. That's why Ni-o-nel alloy has unique staying power in mixtures containing nitric acid, cupric or ferric sulfate.

Ni-o-nel alloy resists most organic acids...gives excellent protection against boiling acetic acid and acetic-formic mixtures. And its properties make Ni-o-nel alloy a good choice for heat exchanger parts subject to pitting and stress corrosion — by sea water and other chloride-containing waters.

Wide selection of Ni-o-nel alloy forms

Plate . . . pipe . . . extruded tubing . . . seamless condenser tubing: Ni-o-nel alloy is available in all standard mill forms, all easily fabricated. With the proper rods, Ni-o-nel alloy provides welds as strong and corrosion-resistant as the parent metal. Write for Technical Bulletin T-37, "Engineering Properties of Ni-o-nel." And let us know your problems with metals in corrosive conditions. Perhaps we can help you find the best answers. *Inco trademark

HUNTINGTON ALLOY PRODUCTS DIVISION
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NI-O-NEL®

Gleekman

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McFarland

Stull

Nominating Committee Names Slate of 1961-62 Officers

Nominations of candidates for election to the highest offices in NACE have been received from the nominating committee. Officers elected will serve for the 1961-62 term. E. C. Greco is nominated for president, Rolland McFarland, Jr., for vice president and C. G. Gribble, Jr., for treasurer.

Nominated for terms on the board of directors are Frank E. Kulman to represent NACE active members and F. D. Stull and L. W. Gleekman to represent corporate members.

Nominations made by the committee can be supplemented by nominations from active NACE members in accordance with Paragraph 3 of Section 3, Article VIII of the NACE Articles of Organization which states:

"Not later than a date to be fixed as provided in Section 5 of this Article, (Article VIII). The Secretary shall inform all members of the Association, by publication or otherwise, of the list of nominees reported to him by the Nominating Committee; and at any time prior to a later date, to be fixed as provided in Section 5 of this Article, additional nominations may be made by petition forwarded to the Secretary and signed by at least twenty-five (25) active members. Any such nominees for the office of President, Vice President or Treasurer shall qualify as provided in the first paragraph of this section."

As indicated by the schedule published on this page, active members have until July 10 to submit the names of additional nominees by petition. Voting will be by letter ballot in August. Deadline for votes to be in Central Office will be September 23. Tellers will have until November 1 to prepare their report of the ballot count.

BIOGRAPHIES of NOMINEES

E. C. GRECO, senior research chemist for the United Gas Corporation, Shreveport, La., was elected NACE vice president for 1960-61. A member of NACE since 1946, he has been president of the Louisiana Academy of Sciences, state director for the American Association for the Advancement of Sciences and state director of Science Fairs which he organized in 1957. He is past chairman and councilor of the Ark-La-Tex Section of the American Chemical Society.

His activities in NACE include chairman and vice chairman of the Technical Practices Committee and chairman of technical committees investigating corrosion in oil and gas well equipment. He is the author of three technical papers published in CORROSION. He also served as secretary-treasurer of the South Central Region in 1956. He is a graduate of Northwestern Louisiana State College.

ROLLAND McFARLAND, Jr., secretary and technical director of the Hills-McCanna Company, Chicago, Ill., has been engaged in design and application of pumps, valves and allied equipment for over 20 years. An NACE member since 1948, he has been chairman of Technical Committee T-6A and is currently an NACE director representing active membership. He also is a member of AIChE, ACS and ASM and is a graduate of Armour Institute of Technology's school of chemical engineering.

C. G. GRIBBLE, Jr., district manager for Metal Goods Corporation, Houston, Texas, was elected treasurer of NACE for 1960-61 and has been re-nominated for that office. A corporate member of NACE since 1954 and a member since 1948, his NACE activities have included membership on the Board of Directors as representative for corporate members, local arrangements committee chairman for the 1952 Annual Conference in Galveston, co-chairman for exhibits at the 1957 Conference in St. Louis and chairman of the Houston Section.

FRANK E. KULMAN is senior engineer with Consolidated Edison Company of New York, Inc., New York City, where he has been employed for 34 years. An NACE member since 1946, he also is a member of AGA, AIEE and NSPE. He has a masters in electrical engineering from Polytechnical Institute of Brooklyn. His work in NACE has included chairman of the Metropolitan New York Section, chairman and membership in several technical group committees and currently member of the Editorial Review Committee.

L. W. GLEEKMAN, supervisor of the Materials Engineering Group, Engineering and Development Division of Wyandotte Chemicals Corporation, Wyandotte, Mich., has been a member of NACE since 1953 and a corporate member since 1954. His NACE activities include chairman of the Detroit Section, member of several technical committees, chairman of T-5A-4 (1957-58), and technical program chairman for the 1956 North Central Region Conference. He also is a member of ASM AIChE and ASEE. He has an MS and PhD in chemical engineering from the State University of Iowa.

FRED D. STULL, superintendent of Corrosion Prevention with Texas Gas Transmission Corporation, Owensboro, Kentucky, is a charter corporate member of NACE. His activities in the association have included chairmanship of the Southeast Region. He received his education at Austin College, Rice Institute and Georgia School of Technology. For the past 25 years of his 30 years with Texas Gas Transmission and its predecessor companies, he has specialized in corrosion control work.

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The 21st NACE Conference and 1965 Corrosion Show will be held at the Chase-Park Plaza Hotels, March 13-18, 1965, in St. Louis, Mo.

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The 20th NACE Conference and 1964 Corrosion Show is scheduled for March 9-13, 1964, at the Sherman Hotel, Chicago, Illinois.

OFFICIAL REPORT NOMINATING COMMITTEE

The Nominating Committee at its March 18 meeting selected the following nominees for officers and directors for terms beginning March 17, 1961:

For President:
E. C. Greco, United Gas Corporation, Shreveport, Louisiana.

For Vice President:
Rolland McFarland, Jr., Hills-McCanna Co., Chicago, Illinois.

For Treasurer:
C. G. Gribble, Jr., Metal Goods Corporation, Houston, Texas.

For Director to represent active membership:
Frank E. Kulman, Consolidated Edison Company of New York, Inc., New York City.

For Director to represent corporate membership: (two to be elected)
Fred D. Stull, Texas Gas Transmission Corp., Owensboro, Kentucky.
L. W. Gleekman, Wyandotte Chemicals Corp., Wyandotte, Michigan.

Schedule of Dates for Nomination and Election of National Officers and Directors for Terms Beginning March 17, 1961

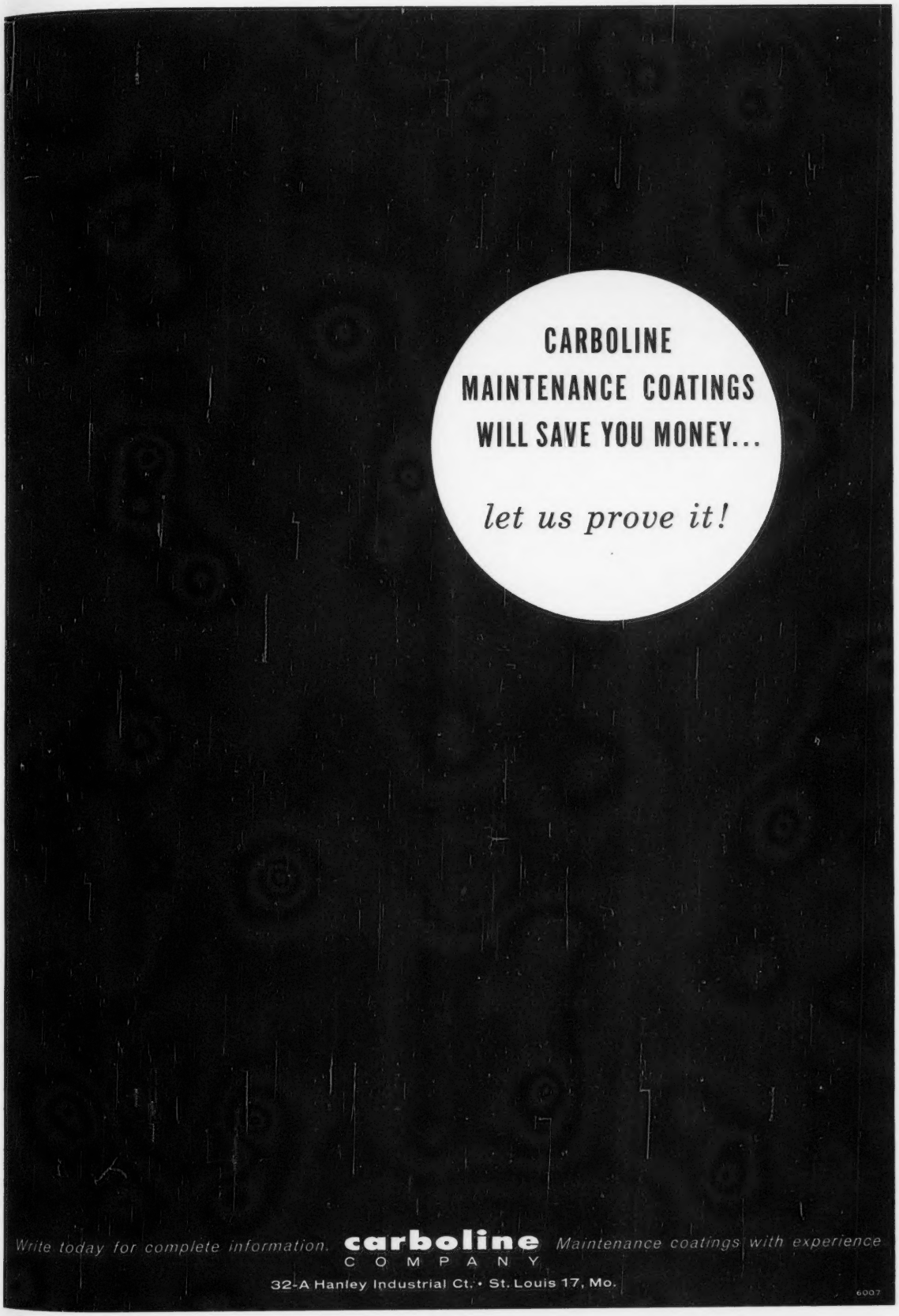
ACTIVITY	DATE TO BE COMPLETED
Formation of Nominating Committee (completed)	March 18, 1960
Nomination of Candidates and report to the Secretary (completed)	April 1, 1960
Publication of Nominating Committee report	May 1960 issue of CORROSION
30 to 35 days for members to prepare and file nominations by petition	June 10, 1960
Preparation and mailing of letter ballots to NACE members	July 21, 1960
Period allowed for members to return letter ballots	September 23, 1960
Period allowed to count ballots and prepare report by tellers	November 1, 1960
General Business Meeting	March 15, 1961

List of Members Eligible for Nomination to the Office of President, Vice President or Treasurer of NACE for the Term Beginning March 17, 1961.

J. P. Barrett, N. E. Berry, H. L. Bilhartz, J. D. Bird, R. A. Brannon, E. G. Brink, H. R. Brough, J. A. Caldwell, J. Pat Casey, Jr., W. R. Cavanagh, Stephen P. Cobb, F. E. Costanzo, Stephen D. Day, Irwin C. Dietze, L. B. Donovan, J. S. Dorsey, W. F. Fair, Jr., M. G. Fontana, L. W. Gleekman, E. C. Greco,* C. G. Gribble, Jr., H. F. Haase, Norman Hackerman, H. L. Hamilton, Derk Holsteyn, A. N. Horne, R. B. Hoxeng, L. A. Hugo, H. A. Humble, V. N. Jenkins, T. F. P. Kelly, V. V. Kendall, W. J. Kretschmer, R. E. Kuster, F. L. LaQue, C. P. Larrabee, R. J. Law, R. H. Lynch, R. McFarland, Jr., George B. McComb, F. J. McElhatton, T. J. Maitland, V. V. Malcom, T. P. May, R. B. Mears, E. F. Moorman, C. G. Munger, A. R. Murdison, W. R. Myers,

* Eligible for nomination for President only.

(Continued on Page 60)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6007

Subscription Rates Raised for Some Foreign Countries

An increase in subscription rates for CORROSION to addresses outside the North American Continent has been approved. The new rates will be put into effect as soon as possible after notices have been sent to all subscribers and subscription agencies affected.

The decision was made on recommendation of the Publication Committee after several years' delay. The committee had been reluctant to increase the rate of subscriptions going abroad in the belief that it might affect the wide distribution of information on corrosion control presently obtained through the magazine's distribution in some 70 countries.

Increased postal rates and a growing number of missing copies which must be replaced at no cost to the subscriber have so increased the cost of handling subscriptions outside the North American continent that the added expense no longer can be absorbed. The rate of replacement of lost or damaged copies for subscribers abroad is much greater than the rate for similar reasons on this continent.

Another factor which was taken into account was the administrative problems involved in handling subscriptions abroad. Because of difficulties in communication, necessity for obtaining exchange, and in some cases poor postal service, the cost of administering subscriptions abroad is greater than for those in the United States and adjacent countries.

Letters to the Editor

March 28, 1960
New Haven, Conn.

As a member of NACE, and interested, as all members should be in our national economy, I wish to thank you for your fine editorial on "The Fallacy of Built-In Obsolescence" appearing in the current issue of CORROSION Magazine.

I wish a copy of this editorial could be sent to every motor car manufacturer in this country, as well as to every popular magazine read by the public. It is really high time the public became aware of this terriffic national waste.

(signed)
Harry F. Brown

Technical Committee Report Price Schedule to Be Set

Executive Secretary T. H. Hull has been instructed by the NACE Board of Directors to establish a schedule of prices for the sale of NACE Technical Committee Reports which is higher than prices charged for copies of other technical literature. The board's decision was reached after a discussion in which the consensus developed that reports, being the considered work of the association, are more valuable than contributions by individuals or companies alone.

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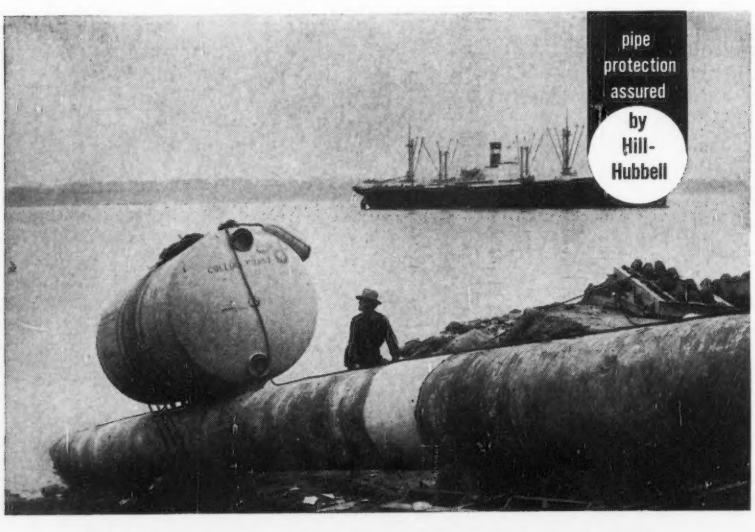
Certificates for past chairmen of regions and sections, measuring 9 x 12 inches, are available from the Central Office at $7.50 each.



vital narrows crossing *fully protected*

This underwater pipeline across New York Harbor "Narrows" will serve Brooklynites for many years, thanks to optimum corrosion protection applied by Hill-Hubbell.*

Underwater or underground, long, trouble-free service is assured if you specify Hill-Hubbell — the name synonymous with quality in mill coated-and-wrapped pipe.

*Pipe in photo weighted with concrete covering over Hill-Hubbell protection.

Specify Hill-Hubbell wrapped pipe on your next job . . .

HILL·HUBBELL
DIVISION OF GENERAL PACIFIC CORP.

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Minor Arrangement Changes Authorized for "Corrosion"

Some minor changes in the internal arrangement of the Sections of CORROSION were authorized at meetings of the NACE Publication Committee at Dallas in March. These included transposition of the Record and Report section with the Technical Committee Activities and NACE News sections. This will put all editorial material relating to technical and engineering matters in sequence.

The page containing the monthly editorial will be moved to Page 7 from the position it has occupied since January. The committee expects this change will get more attention for the editorial.

A monthly list of advertised products and services will be published. This is expected to be of material assistance to those who are searching for products and services to meet specific needs and solve pressing problems.

1960 Corrosion Show Color Slide-Talk

A show consisting of 108 color slides has been prepared showing some of the exhibits at the March 15-17 Dallas exhibition. This 1960 Corrosion Show color slide presentation will be accompanied by a commentary describing the exhibits and many of the items displayed.

NACE Section program chairmen who are interested in using this in one of their programs may make bookings by writing to G. A. Rolak, 1061 M & M Bldg., Houston 2 Texas.

The show gives members who were unable to attend the conference an opportunity to see some of the exhibits at what many have said was the best Corrosion Show held so far.

Nominating Committee–

(Continued From Page 58)

E. P. Noppel, G. R. Olson, Miss Ivy M. Parker, R. R. Pierce, W. F. Rogers, J. E. Rench, L. F. Scherer, H. W. Schmidt, L. R. Sheppard, Edward L. Simons, A. D. Simpson, Jr., A. B. Smith, D. E. Stearns, A. L. Stegner, E. H. Tandy, R. S. Treseder, H. C. Van Nouhuys, E. D. Verink, Jr., Aaron Wachter, H. E. Waldrip, L. C. Wasson, T. R. B. Watson, John B. West, F. L. Whitney and Guy F. Williams.

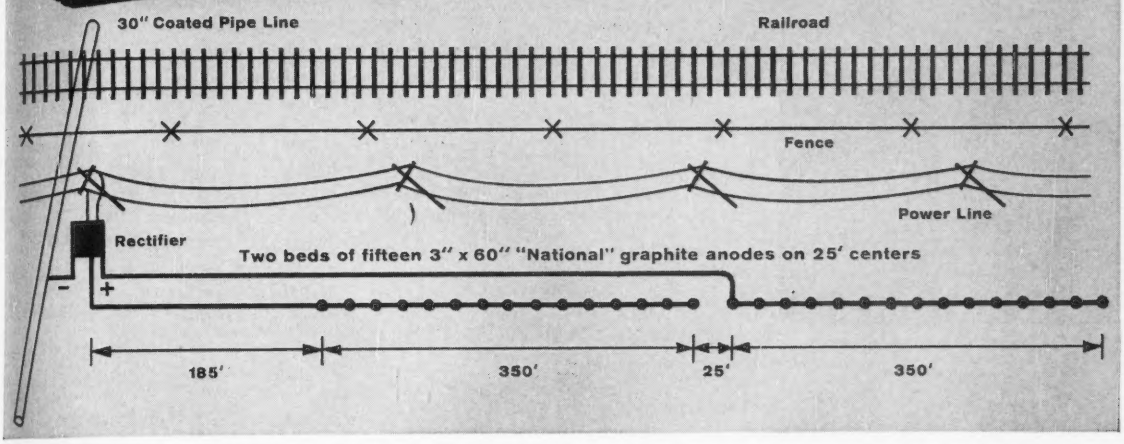
Any Active Member in good standing is eligible for nomination as a Director to represent the Active Membership of the Association, and any Representative of a Corporate Member in good standing is eligible for nomination as Director to represent the Corporate Members of the Association, except the following who are not eligible for nomination as an elected director for the term beginning March 17, 1961—because of the time limitation in Section 5, Article IV of the Articles or Organization.

List of Members not Eligible for Nomination as Director for Term Beginning March 17, 1961.

J. P. Barrett, G. E. Best, H. L. Bilhartz, J. D. Bird, R. A. Brannon, E. G. Brink, F. E. Costanzo, J. S. Dorsey, H. P. Godard, E. C. Greco, C. G. Gribble, Jr., H. F. Haase, H. L. Hamilton, R. E. Kuster, R. McFarland, Jr., T. J. Maitland, E. F. Moorman, A. R. Murdison, J. E. Rench, E. L. Simons, A. B. Smith, A. L. Stegner, W. H. Stewart, E. H. Tandy, R. S. Treseder, H. E. Waldrip, L. C. Wasson, T. R. B. Watson, J. B. West, L. L. Whiteneck and Guy F. Williams.

Anode notes from

National Carbon Company



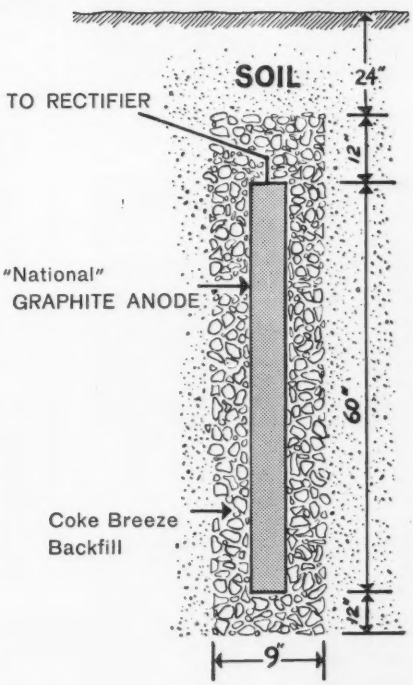
PROTECTION OF 645 MILES OF 30 INCH COATED STEEL PIPE LINE

In 1954 the management of a large oil company decided to protect part of their new transmission system. Since time was short they decided to contract for a turnkey cathodic protection job.

The contractor's* corrosion engineers surveyed the entire line and installed eighteen 24 volt rectifiers with 10-20 amp capacity to power the associated "National" graphite anode beds. The beds had from ten to fifty 3" x 60" graphite anodes in coke breeze backfill on 25 ft. spacing.

After the system was energized in 1955, the corrosion engineers tested and made necessary bonds with over 60 "foreign owned" pipe and cable crossings and adjusted the entire system to provide a potential of —.85 volts pipe to soil potential over its entire length.

A complete survey in 1959 showed that the anode beds are all performing satisfactorily. Several new "National" graphite anode beds will be installed to protect additions to the original pipe line. For data on graphite anodes, contact National Carbon Company, Division of Union Carbide Corporation, 270 Park Avenue, New York 17, New York. In Canada, Union Carbide Canada Limited, Toronto.



*Harco Corporation, Cleveland, Ohio

"National", "N" and Shield Device, and "Union Carbide" are registered trade-marks for products of

NATIONAL CARBON COMPANY

UNION CARBIDE

North Central Region

Dennison

Eberhardt

Haase

Huseby

Johnson

McConnell

Quick

Walczyk

Wasson

Wilson

Conference Chairmen Appointed for 1960 Milwaukee Conference

The Eastern Wisconsin Section will be host for the 1960 North Central Region Conference scheduled for October 19-20 at Hotel Pfister, Milwaukee, Wis. Technical meetings will include symposia on corrosion problems in the chemical process, brewing, pulp, paper and utilities industries.

Technical committee meetings and a regional business meeting will be held during the conference. Inquiries on technical committee meetings should be directed to L. C. Wasson, technical program committee chairman, A. O. Smith Corp., Milwaukee, Wis.

Co-chairmen of the General Conference Arrangements Committee are Alexander McConnell of George J. Meyer Mfg. Co., and R. A. Huseby of A. O. Smith Corp.

Other conference committee chairmen are listed below:

L. C. Wasson of A. O. Smith Corp., technical program; D. D. Walczyk of A. O. Smith Corp., local and physical arrangements; David H. Wilson of Metal Spraying Co., entertainment; Thomas E. Quick of Ladish Co., registration; T. E. Johnson of Stainless Foundry & Engineering, Inc., publicity and printing.

Financial chairman will be P. G. Dennison of Metal Spraying Company.

Conference adviser is Harold F. Haase, a consulting engineer. Conference secretary is Robert D. Eberhardt of Allis-Chalmers Mfg. Co.

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Southwestern Ohio Section heard John Frank of National Distillers and Chemical Corporation speak on approaches to corrosion problems in distillery operations at the March 29 meeting.

•

Detroit Section held a joint meeting with ASTM and the Electrochemical Society sections to hear Frank L. LaQue of International Nickel Co., Inc., speak on the subject "What We Know and Don't Know About Corrosion."

•

Chicago Section scheduled Richard G. Dalbke of Dearborn Chemical Company as guest speaker for the April 19 meeting. His topic was "Modern Methods for Control of Corrosion in Cooling and Potable Water Systems."

CERTIFICATES of MEMBERSHIP in NACE

Certificates of membership in the National Association of Corrosion Engineers will be issued on request at $2 each, remittance in advance. The certificates, which measure 5½ x 8½ inches, are signed by the president and executive secretary of the association.

CERTIFICATES for PAST CHAIRMEN of REGIONS and SECTIONS

Certificates measuring 9 x 12 inches in size, prepared from an engraved plate, are available for issuance to regional and sectional chairmen. They will be supplied on request of the region or section at $7.50 each to be paid by the region or section, the cost to be classified as a non-reimbursable expenditure.

Address Orders to

T. J. Hull, Executive Secretary

NATIONAL ASSOCIATION OF CORROSION ENGINEERS

1061 M & M Bldg., Houston 2, Texas

Twin Cities Section to Be NACE's 61st Local Unit

NACE's 61st section has been formed. Approved by the officers and trustees of the North Central Region, the new section has been named the Twin Cities Section. It will include the Minneapolis-St. Paul area.

Temporary officers are Chairman Charles C. VanRickley and Secretary James F. Williams.

Shaft Sinking Record Set

The world shaft sinking record held by Russia was broken recently at the Vaal Reef Mine in Orkney (Western Transvaal), Africa. The crew dug 922 feet in 30 days, bettering the Russian record of 868 feet. Present depth of the Vaal Reef shaft is 2054 feet and is planned to a depth of 7200 feet, probably the deepest vertical shaft in the world.

Aluminum Rocket Engines

Possible use of aluminum in rocket engine cases may result from tests indicating aluminum is stronger than steel on a weight basis, according to the Aluminum Company of America. Tests showed that an aluminum engine under severe stresses could "give" five percent without exploding.

Federation Name Change

Name of the Federation of Sewage and Industrial Wastes Associations has been changed to Water Pollution Control Federation. The Federation's journal will be titled "Journal of the Water Pollution Control Federation."

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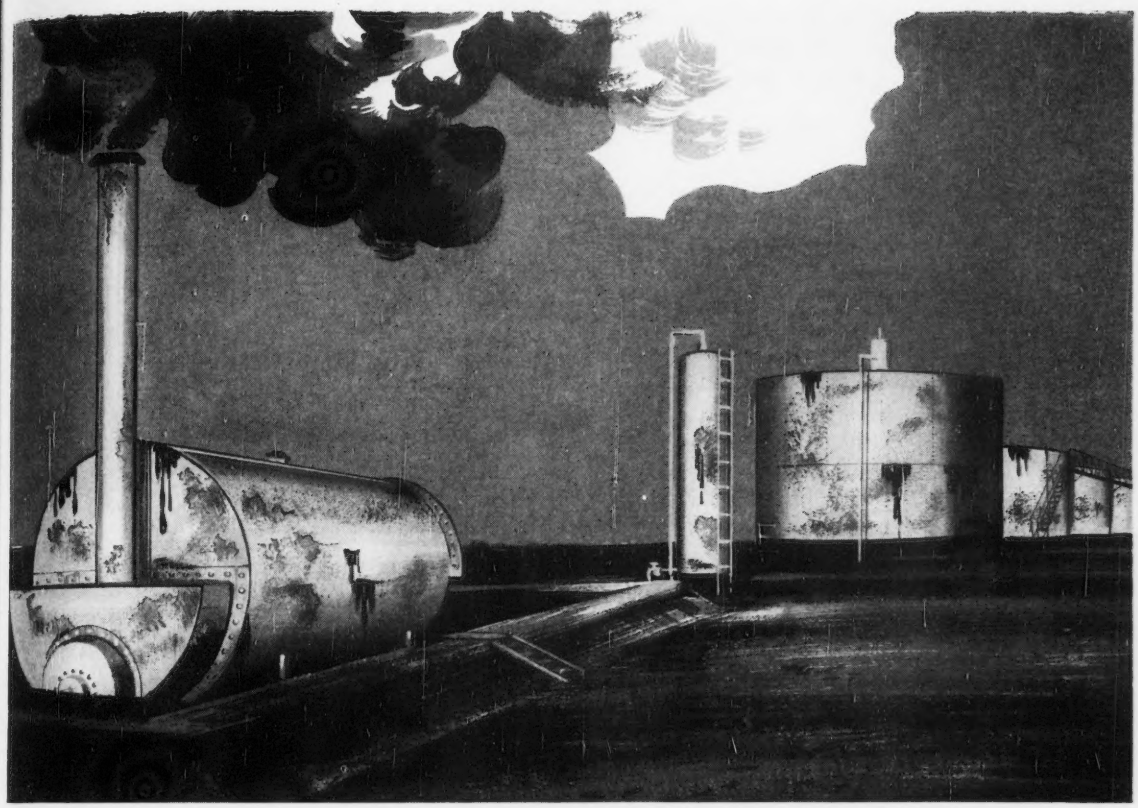
NACE's 17th Annual Conference and 1961 Corrosion Show will be March 13-17, 1961, at the Hotel Statler in Buffalo, N. Y.



Is your equipment going up in smoke too?

CPS Heater Treater Cathodic Protection will prevent this loss.

INTERNAL CORROSION of oil field equipment, handling produced brine, can be entirely eliminated by the application of soundly engineered cathodic protection installations. Vessel equipment does not wear out — it corrodes out.

Either your nearest CPS branch office or our home office is readily available for engineering consultation to . . . properly design your cathodic protection systems.

CPS Heater Treater cathodic protection equipment can be procured through your nearest Tank Company — our home office or any of our listed branches.

CPS has also been involved in the engineering and installation of cathodic protection of several thousand well casings and is presently engaged in the installation of cathodic protection on over 500 casings for a Unit Operator in West Texas.

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RIverside 2-7393

CORPUS CHRISTI
1620 S. Brownlee
TUlip 3-7264

ODESSA
5425 Andrews Hwy.
EMerson 6-6731

1960 WESTERN REGION CONFERENCE CHAIRMEN who will make arrangements for the October 6-7 conference to be held at the Sheraton-Palace Hotel, San Francisco, are shown above. In the back row, from left to right, are George E. Moeller of Union Oil Co., program chairman; David Haas of Amercoat Corp., hospitality chairman; A. E. Storm of Tidewater Oil Co., chairman of the Western Region; William R. Garratt of Garratt-Callahan Co., ladies program; James B. Dotson of Pyromet Co., publicity chairman, and W. P. Simmons of Alloy Products Co., arrangements chairman. In the front row left to right are S. A. Firpo of Pacific Metals Co., Ltd., assistant registration chairman; George W. Davis of Pacific Metals Co., Ltd., registration chairman; G. J. Puckett of Dow Chemical Co., general chairman; Arthur Bayce of Shell Development, facilities chairman; Martin K. Webber of Shell Development, assistant program chairman and Ernest W. Haycock of Shell Development, assistant facilities chairman.

POSITIONS WANTED AND AVAILABLE

Active and Junior NACE members and companies seeking salaried employees may run without charge two consecutive advertisements annually under this heading, not over 35 words set in 8 point type. Advertisements to other specifications will be charged for at $10 a column inch.

Positions Available

Wanted by Centre Belge d'Etude de la Corrosion: An engineer and a PhD in chemical sciences and a technical engineer for scientific and technical studies in electrochemistry and corrosion. Good basic education and proficiency in languages indispensable. Begin immediately if possible. Write Cebelcor, 24, Rue de Chavaliers, Brussels 5, Belgium.

Chemical Engineer for corrosion inspection program. Involves process corrosion studies, materials testing, process equipment inspection, metallurgical studies and interpretation. Prepare comprehensive reports. Up to 3 years' experience in this field. Write N. B. Russell, P. O. Box 1311, Monsanto Chemical Company, Texas City, Texas.

GAS ENGINEER

Fast growing and progressive midwest natural gas utility, with over 16,000 customers is seeking an engineer with at least 3 or 4 years' gas utility operation experience since graduation to take a position in a supervisory capacity. Prefer man about 30 years of age with technical background and experience in corrosion and cathodic protection and with executive ability to supervise this type of work. Send full resume of experience, age and salary requirements. CORROSION, 60-18.

UNUSUAL OPPORTUNITY

Technical service and sales work for sanitary or petroleum engineer with experience in water flooding. Salary and commission. Write fully, including recent photograph, to Buckman Laboratories, Inc. Memphis 8, Tennessee.

Positions Wanted

Experienced Sales & Service Representative. Chemical education with ten years' experience in laboratory and sales of coatings and chemicals. Desires position with reputable organization for western Pennsylvania area. Best references. CORROSION, Box 60-16.

Electrical-Corrosion Engineer—10 years' experience in mining, oil and consulting operations, foreign and domestic. Speak Spanish. Desire supervisory position with growth potential. Will relocate. Age 34, married. Resume on request. CORROSION, Box 60-17.

Chemical Engineer, B.S. 1957, desires to enter corrosion work on full-time basis. Experience in natural gasoline plant with work in corrosion control and cathodic protection. Any offer in corrosion field considered. Reply: CORROSION, Box 60-19.

Manufacturers' Agents

Manufacturer's Representative wanted to represent established pressure sensitive tape manufacturer in the sale of Pipe Wrap Polyethylene Tapes. Must be entirely familiar with the transmission and utility suppliers. Send complete resume of territory covered, experience, etc. to CORROSION, Box 60-14.

Opportunity—Complete line of corrosion control coatings, floorings etc, offered by firm with excellent technical reputation and straight-forward sales policies. Aggressive but service minded agents wanted for several exclusive territories. CORROSION, Box 60-15.

Western Region

San Joaquin Valley Section has scheduled meetings for June 14, October 25 and December 13. These meetings will be held at Maison Jaussaud's Restaurant in Bakersfield, Cal.

Officers for the section are Chairman Robert M. Evans, Standard Oil of California, Vice Chairman Bruce A. Grover, Western Gulf Corp., and Secretary-Treasurer Nat G. Haseltine, Standard Oil of California.

San Francisco Bay Area Section scheduled Troy J. McCormick of McCormick's Chemical and Inspection Co., San Leandro, to speak on chemical cleaning in industry for the May 10 meeting.

At the April 12 meeting, T. R. Thierry of Resistoflex Corporation spoke on the manufacture, application and economics of Teflon-lined piping.

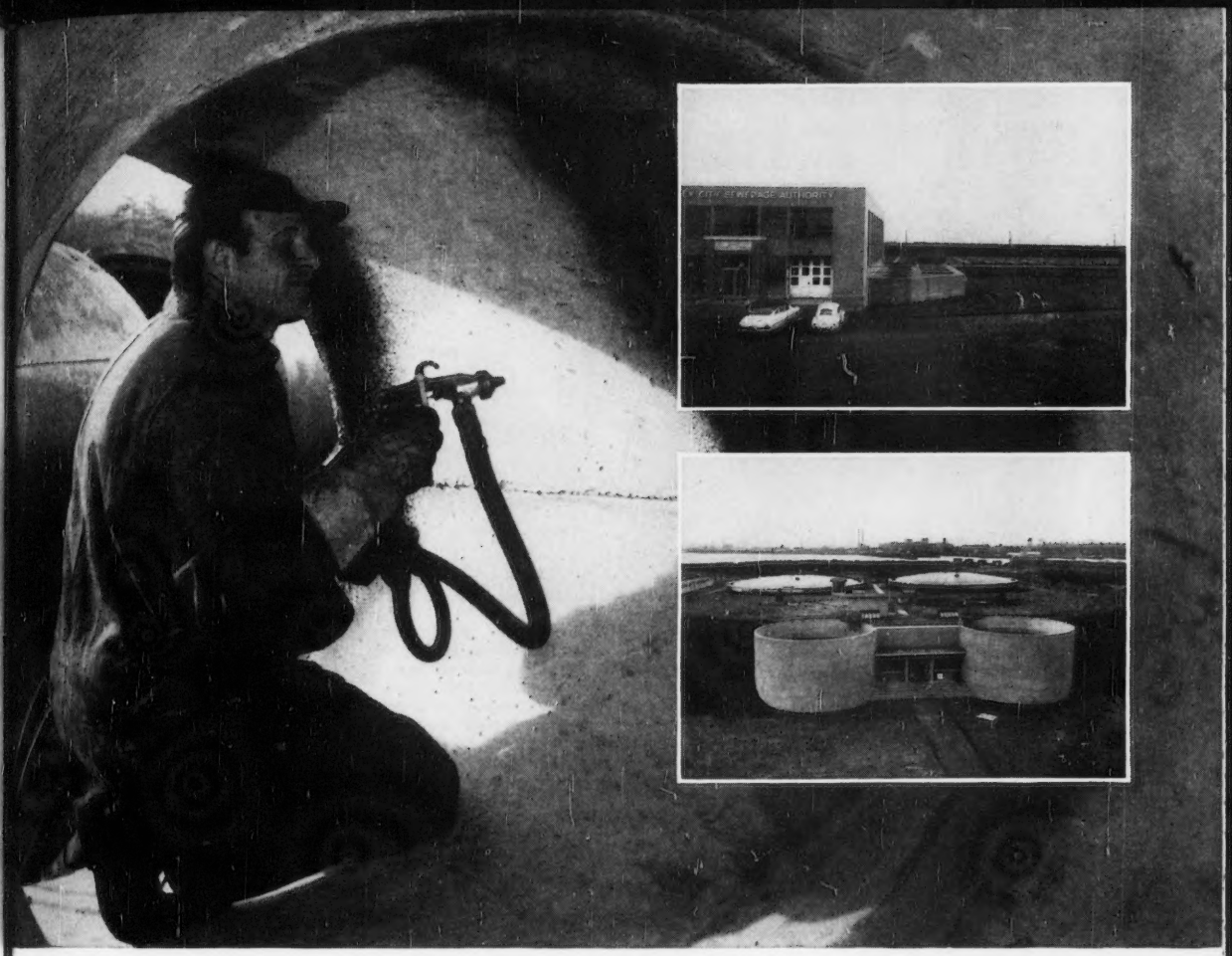
SECTION CALENDAR

May

5 Schenectady-Albany-Troy Section. Oxidation of Iron Chromium Alloys, by C. E. Birchenall.
5 West Kansas Section.
5 Pittsburgh Section. Plant tour of U. S. Steel's National Tube Division, McKeesport, Pa.
6 Birmingham Section. Above Ground Corrosion, by T. G. Humphreys, Jr., Alabama Gas Corp.
9 Greater St. Louis Section. Newness of Thin Film Linings, by W. P. Cathcart, Tank Lining Corp., Pittsburgh, Pa,
10 San Francisco Bay Area Section.
10 Permian Basin Section.
11 Greater Boston Section. Election of officers. Analysis of Furane and Other Plastics in Corrosion Control, by John Delmonte, Furane Plastics, Los Angeles.
17 Chicago Section. Cost Evaluation.
18 Los Angeles Section.
19 Detroit Section. Forum discussion and exhibit on non-destructive testing for corrosion control.
23 Tulsa Section.
26 Edmonton Section.
26 Sabine-Neches Section.
31 Panhandle Section.
31 Philadelphia Section. Metallizing—State of the Art.
31 Southwestern Ohio Section. Corrosion Prevention by Bituminous Coatings, by Donald Burke, Philip Carey Mfg. Co. To be held in Cincinnati.

June

13 Central Oklahoma Section Ladies' Night.
14 Shreveport Section. Annual Barbeque.
14 San Joaquin Valley Section. Maison Joussand's Restaurant, Bakersfield, Cal.



In Jersey City's Sewerage System

H_2S no danger to concrete pipe protected by Bitumastic Coatings

Some 17 miles of large diameter concrete storm and sanitary interceptor lines were laid to link Jersey City's existing mains to the new East and West Side treatment plants. These plants, opened in 1957, have a design capacity of 83 mgd.

To insure maximum life from the concrete pipe used in the lines, Clyde Potts Associates, consulting sanitary engineers for the Jersey City Sewerage Authority, specified that the pipe be given two coats of Bitumastic Super-Service Black on all interior surfaces. This was done in the yards of the pipe suppliers: Look Joint Pipe Co., and the American Concrete Pipe and Universal Concrete Pipe Companies, now part of American-Marietta. The sprayed applications of this coal-tar coating filled and sealed the concrete, increasing its impermeability to raw sewage.

According to Mr. James Dolan, Superintendent and Chief Engineer of Jersey City's system, "Periodic inspections of the lines have shown no failures of the protective coating system for sewer gas attack on the pipe."

Wherever concrete or metal surfaces are exposed to sewage gases, sanitary engineers have found that tough, impervious Bitumastic coatings solve the problem of corrosive attack.

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South Central Region

SHREVEPORT SECTION meeting for April 5 was a color slide presentation on the 1960 Corrosion Show and a review of a technical committee meeting at the Dallas Conference given by Frank Therrell (second from left) of Interstate Oil Pipeline Company. Section chairman Robert P. Naremore of Arkansas Fuel Oil Corporation presided at the meeting.

First Showing of Corrosion Show Slide-Talk Given

A pilot run on the slide presentation of the 1960 Dallas Corrosion Show was made before an audience of 26 members and guests of Shreveport Section April 5. The dinner meeting was held at the Captain Shreve hotel, Shreveport.

The slide talk, consisting of over 100 color photographs of exhibits at the Dallas Corrosion Show was presented by R. W. Huff, Jr., NACE Exhibits manager. Dale Miller, editorial assistant for CORROSION magazine gave the commentary. Among the guests present was Norman Hamner, managing editor of CORROSION.

Shreveport Section has scheduled its annual barbecue for the afternoon of June 14 at the Texaco Club House. The section also is considering presenting other plaques or certificates to its past chairmen.

•

Permian Basin Section heard W. A. Edwards, Sr., of Superior Oil Co., Houston, present a paper on corrosion problems, detection and control practices in reducing operations for the March 8 meeting. Leonard Villalon of Halliburton Oil Well Cementing Co., Duncan, Okla., gave a paper on repair of oil well casing by use of glass-plastic liners at the February 9 meeting.

•

Greater Baton Rouge Area Section meeting for March 21 was a paper on cathodic protection of a tape coated pipeline from Baton Rouge to Miami. Paper was presented by Ralph B. Pass of Cathodic Protection Service.

•

Tulsa Section had guest speaker A. J. Freedman of Nalco Chemical's Research Laboratory talk on cooling water corrosion problems for the April 25 meeting.

•

Central Oklahoma Section will hold a Ladies' Night meeting, June 13 at the Tropical Cafeteria in Oklahoma City. Guest speaker will be Mark Weaver, who will talk on elimination of air accidents.

J. D. Sudbury of Continental Oil Company is scheduled to speak on oxygen corrosion of steel in the petroleum industry at the May 9 meeting, to be held at the Jens Marie Hotel.

North Texas Section scheduled John W. Nee of Briner Paint Co., Corpus Christi, to speak on the effect of atmospheric environment on corrosion rates of steel for the April 11 meeting.

•

Houston Section heard Joseph E. Rench of Napko Corporation speak on comparative testing of coatings for the April 12 meeting.

•

Teche Section had 49 members and guests at its April 6 meeting. Harry E. Waldrip of Gulf Oil Corp., Houston, spoke on practical aspects of production corrosion. A special guest was Cyrus Naghshinch of the Irania Petroleum Corp., Mashur, Iran. He is studing production and corrosion control methods in this country.

•

East Texas Section heard Marvin Reichle of Plastic Applicators, Inc., Houston, speak on use of rubber and plastic in the oil field for the March 22 meeting.

•

Alamo Section reviewed highlights of the Dallas Conference for its April 12 meeting. Discussion leader was Carl Thorn of Southwestern Bell Telephone.

Two films produced by International Nickel were shown for the March 15 meeting. The films were "Refining Nickel From the Sudbury Ores" and "Refining Copper From the Sudbury Nickel Ores."

Plastic Pipe Standard Set

A proposed commercial standard on flexible polyethylene pipe, incorporating minimum wall thickness requirements, was approved by the Thermoplastic Pipe Division of the Society of the Plastics Industry, Inc., at its conference held recently in San Francisco.

The proposed standard also contains performance requirements including a sustained pressure test and an environmental cracking test. The standard has been forwarded to the U. S. Department of Commerce.

1960

May 26-27—NACE Board of Directors Meeting, Rice Hotel, Houston, Texas.

Oct. 6-7—10th Annual Western Region Conference, Sheraton-Palace Hotel, San Francisco, Cal.

Oct. 6-8—Southeast Region Conference, Dinkler-Plaza Hotel, Atlanta, Ga.

Oct. 11-14—Northeast Region Conference, Prichard Hotel, Huntington, W. Va.

Oct. 19-20—North Central Region Conference. Pfister Hotel, Milwaukee.

Oct. 25-28—South Central Region Conference, Mayo Hotel, Tulsa.

November 17-18—NACE Board of Directors Meeting, Sherman Hotel, Chicago, Ill.

1961

March 13-17—17th Annual Conference and 1961 Corrosion Show, Buffalo, N. Y., Hotel Statler.

Oct. 4-6—Western Region Conference, Hotel Multnomah, Portland, Oregon.

Oct. 9-11—North Central Region Conference, St. Louis, Chase Park Plaza Hotel.

Oct. 24-27—South Central Region Conference, Houston, Shamrock Hotel.

Oct. 30-Nov. 2—Northeast Region Conference, New York City, Hotel Statler.

Southeast Region Conference, Miami, Fla., in conjunction with Miami Section's short course.

1962

March 19-23—18th Annual Conference and 1962 Corrosion Show. Kansas City, Municipal Auditorium.

October 1-4—Northeast Region Conference, Hotel Sheraton Ten Eyck, Albany, N.Y.

October 9-11—North Central Region Conference.

October 16-19—South Central Region Conference, Hilton Hotel, San Antonio, Texas.

Southeast Region Conference, Birmingham, Ala.

Western Region Conference. San Diego, Cal.

SHORT COURSES

1960

May 11-13—Niagara Frontier Section Symposium on Organic Coatings. Hotel Niagara, Niagara Falls, N. Y.

June 1-3—5th Annual Appalachian Underground Corrosion Short Course, West Virginia University, Morgantown, W. Va.

September 12-16—Short Course on Process Industry Corrosion, sponsored by NACE Technical Committee T-3 and Ohio State University, to be held at Ohio State University, Columbus.

September 28-30—Central Oklahoma Section 1960 Corrosion Control Short Course, at University of Oklahoma, Norman.

October 3-5—Corrosion Control Short Course, sponsored by Western Region and University of California, San Francisco.

CORROSION ABSTRACTS

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3. CHARACTERISTIC CORROSION PHENOMENA

3.5 Physical and Mechanical Effects

3.5.4, 6.3.17, 3.7.3

Effects of Pile Irradiation on U_3Si. M. L. Bleiberg and L. J. Jones. Trans. Met. Soc., Amer. Inst. Mining and Metallurgical Eng., **212**, No. 6, 758-764 (1958).

When a uranium-3.8 wt.% silicon alloy is heat-treated to produce the ε-phase intermetallic compound U_3Si, and irradiated to a maximum exposure of 0.104 at .% burn-up and at a maximum in-pile temperature of <250 C, there is a marked decrease (~3.7%) in d and large increases in hardness (the material becoming very brittle) and electrical resistivity—the normal positive temperature coefficient of which reverts to an abnormal negative coefficient. Corrosion-resistance to water at 650 F (345 C) appears to be unchanged, but cracking is prevalent because of high internal stresses in the material. The microstructure appears to be unchanged, but no X-ray-diffraction lines can be found. The results suggest that a neutron-induced disordering reaction occurs during irradiation. 14 references.—MA. 18015

3.5.8, 5.3.4

Protection Against Corrosion Fatigue. (In French.) A. Royez and J. Pomey. Rev. Mét., **56**, 122-128 (1959) Feb.

Corrosion fatigue, which occurs with steels subjected to alternate stressing in the presence of soft water, has the effect of causing the disappearance of the fatigue limit; rupture inevitably occurs after a certain number of cycles which is greater the lower the stress. Paint coatings have practically no notable protective effect; copper plating has a certain, though very limited beneficial effect; electrolytic zinc coating has an excellent effect if followed by chemical chromating; finally, compressive prestressing is very effective if service conditions do not cause the disappearance of the residual stresses; for this purpose, cyaniding and nitriding are particularly efficacious.—BTR. 17834

3.5.8, 3.2.2, 3.7.3, 6.3.6

Stress Corrosion Cracking in Copper Alloy Weldments. R. T. Phebus. Westinghouse Atomic Power Div. J. Am. Soc. Naval Engrs., **70**, No. 3, 543-549 (1958) Aug.

Definition of stress corrosion, factors governing it, occurrence of stress corrosion in ferrous alloys and in non-ferrous alloys and tests for stress-corrosion cracking are reviewed. Investigations at Naval Engineering Experiment Station on stress corrosion failures of Naval brass evaporator shells welded with phosphorus bronze electrodes, and of aluminum bronze distilling units welded by inert-gas metal arc process, revealed that application of post weld annealing reduced internal stresses to value below threshold for stress-corrosion cracking. Stress relieving temperatures were 750 F for Naval brass and 900 F for aluminum bronze unit. Cracking of copper-nickel alloys is mentioned. Diagrams show stiff-frame assembly used for stress corrosion studies. Photomicrographs.—INCO. 17543

3.5.4, 3.8.2, 6.2.5, 6.3.10

Electrochemical and Corrosion Behavior of Steel and Nickel Electrodes in Sulfuric Acid Solutions Subjected to the Action of γ-Rays. (In Russian.) N. Ya. Bune, Ya. M. Kolotyrkin and G. S. Tyuribov. Karpov Inst. of Physics and Chemistry. J. Phys. Chem., USSR (Zhur. Fiz. Khim.), **32**, 2679-2685 (1958) December.

A study was made of the action of γ radiation on the electrochemical and corrosion behavior in 1N sulfuric acid of type 18-8 steel and of nickel, the radiation intensity being 1.5×10^{15} ev/ml sec. For these metals the effective radiolysis components were found to be those with oxidizing properties. It was established that the effect of the radiation on the rate of solution of the metal depends upon its capacity for passivation. For easily passivated metals (steel) the superposition of radiation leads to a decrease in the dissolution rate, for metals (nickel) passivated with difficulty an increase in the rate takes place. The presence of iron ions in the solution leads to an increase in the oxidizing efficiency of the radiation. (auth)—NSA. 18119

3.5.8, 4.3.3, 3.2.2, 6.2.5

Report of Preliminary Stress-Corrosion Cracking Tests of Type-347 Stainless Steel Capsules Containing Sodium Hydroxide. G. E. Galonian and H. L. Tymchyn. Knolls Atomic Power Lab. U. S. Atomic Energy Commission Pubn., KAPL-M-GEG-12, June 18, 1959, 25 pp. Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.

Stress corrosion cracking tests of Type-347 stainless steel were conducted at 636 F for periods up to 1000 hr. with 1- and 4-m sodium hydroxide. A capsule specimen (consisting of 1-in. schedule 40-pipe and welding caps) containing the solutions was evaluated as a test to detect susceptibility to caustic cracking. Stressed U-bend specimens were also tested in the capsules. Eight out of eight capsules not stress-relieved after welding failed in the welds and welded regions by transgranular cracking in approximately 100 hr. Two out of four capsules with stress-relieved welds failed in a thin wall gage section at a stress level of about 22,000 psi. Corrosion in specimens exposed for 1425 hr. was predominately intergranular. One out of eight U-bend specimens (not stress-relieved) failed. The results show that an as-welded capsule-type specimen containing 1- to 4-molal sodium hydroxide at 636 F is a satisfactory test for detecting susceptibility to caustic cracking. (auth).—NSA. 18285

3.5.4, 6.2.5, 8.4.5

Effects of Irradiation on Stainless Steel-Clad UO_2 Pellets in Helium or Carbon Dioxide. Gerald E. Lamale, John E. Gates and Ronald F. Dickerson. Battelle Memorial Inst. U. S.

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Atomic Energy Commission Pubn., BMI-1335, April 21, 1959, 18 pp. Available from Office of Technical Services, Washington 25, D. C.

Uranium dioxide pellets sealed in Type 316 stainless steel containers with a helium gas were irradiated in helium and in carbon dioxide in thermal fluxes of the order of 1×10^{13} n/(cm^2) (sec). Cladding-surface temperatures were reportedly between 1200 and about 1800 F. The hot-cell examination performed by BMI showed that there were no obvious effects of the irradiation on the specimen tested in helium. However, the specimen irradiated in the presence of carbon dioxide exhibited severe cladding-carbon dioxide reaction and possible central melting of the uranium dioxide. Although comparisons between pre- and postirradiation data were difficult because of involved fabrication history of the specimens, the test did further establish the fact that helium is a satisfactory coolant gas for stainless steel cladding material at a temperature of 1200 F. The data obtained from the specimen tested in the presence of carbon dioxide indicate that at temperatures in the range of 1600 to 1800 F Type 316 stainless steel is not compatible with carbon dioxide. (auth)—NSA. 18379

3.5.4, 3.4.8, 6.2.2, 3.7.4

Conditions of Fixation of Radioactive Sulphur on the Surface of Polycrystalline Iron and Its Relationship to Crystal Orientation. (In French.) Bernard Le Boucher, César Libanati and Paul Lacombe. Compt. rend., **248,** 2578-2580 (1959) May 4.

Aqueous or gaseous fixation of S^{35} on surface of iron at room temperature is influenced by presence of oxygen at the metal surface or in corrosive medium. When the presence of oxygen is minimal, the amount of S^{35} deposited is function of crystal orientation.—RML. 18380

3.5.4, 8.4.5, 4.7

Liquid Metal Loops Irradiated in the ORNL Graphite Reactor and the LITR. W. W. Parkinson and O. Sisman. Oak Ridge National Lab. U. S. Atomic Energy Commission Pubn., ORNL-2630, June 1, 1959, 35 pp. Available from Office of Technical Services, Washington, D. C.

Liquid alkali metals were circulated in a series of structural alloy loops under reactor radiation at high temperature. The first of these loops was a lithium-stainless steel (type 316) system, and the remainder were sodium-Inconel. The lithium-stainless steel loop operated at 1000 F with a flow of 2 fps for 160 hr, receiving a fast neutron dose of 3×10^{16} neutrons/cm^2. Three of the sodium loops operated at 1500 F in the in-pile section and 1100 at the pump cell, with flows of 1 to 1.5 fps; the duration of operation ranged from 101 to 235 hr. to give fast neutron exposures of 1.8 to 4×10^{16} neutrons/cm^2. The fourth sodium loop incorporated a stress-corrosion specimen stressed at 1500 psi. This loop operated between 1070 and 1270 F for 159 hr. at a flow of 1 fps through the specimen. The dose ranged up to 5×10^{15} thermal neutrons/cm^2 and 2×10^{15} fast neutrons/cm^2 at the in-pile end of the specimen. In all loops, corrosion, if any, was less than 0.0005 in. No effect of radiation other than radioactivation was found. Mass transfer and metallurgical processes attributable to the operating temperatures were observed. (auth)—NSA. 18539

3.7 Metallurgical Effects

3.7.2, 6.3.15

Titanium-Noble Metal Alloys Greatly Heighten Resistance to Corrosion. Light Metal Age, **17,** 14-15, 30 (1959) June.

Addition of a small amount of some noble metals—0.1% palladium, for instance, decreases the rate of corrosive attack to less than 0.01 inches per year. This remarkable improvement can also be achieved by small additions of most of the other noble metals—platinum, rhenium, ruthenium, iridium, osmium and rhodium. Titanium-palladium has identical properties of unalloyed titanium.—BTR. 18383

3.7.2, 3.2.2, 3.7.3, 6.2.5

Effects of Boron on the Carbonization in Austenite Steel During Annealing. (In Russian.) V. V. Levitin and V. I. Syreischikova. Fiz. Metal. i Metalloved. (The Physics of Metals & Metallography), **7,** 308-310 (1959) Feb. English Translation of Journal Available from Pergamon Inst., 122 East 55th Street, New York 22, New York.

Data on the effects of boron on chromium-manganese-nickel steel (with nitrogen) intercrystalline corrosion after quenching at 1100 C and annealing at 650 C show that boron slows down the formation of carbide formation at the austenite grain boundary.—NSA. 18377

3.7.3, 6.2.2, 3.8.4

Diffusion and Solubility of Hydrogen in Iron and Extra Soft Steels. (In French.) Jacques Plusquellec, Pierre Azou and Paul Bastien. Compt. rend., **248,** 1816-1819 (1959) March 23.

Effect of preliminary cold working at room temperature and at the temperature of liquid air on the solubility of hydrogen in a low carbon steel was studied. Moreover, the coefficient of diffusion was determined at 20 C by using spherical samples. (tr-auth)—NSA. 18488

3.7.3, 3.2.2, 6.2.5

Problems in Stainless Steel Welding Regarding Intercrystalline Corrosion. (In Czech.) Josef Nemec. Zvaranie, **8,** No. 3, 74-78 (1959) March.

After describing various heat treatments and their effects on welded austenitic steel structures such as stabilized steel 17 246, a detailed draft of procedures for testing intercrystalline corrosion resistance of the welds is indicated. The three essential ways of automatic fusion welding (Unter Flux, argon- and carbon dioxide-shielded) with a view to attaining perfect stabilization of the weld metal, are compared. —BTR. 18537

3.7.3, 6.2.5, 3.2.2, 4.3.2

Corrosion of Welded Stainless Steels in Acid Solutions. M. M. Kurtepov and A. S. Gryaznova. Inst. of Physical Chemistry. Metalloved. i. Termich. Obrabotka Metal., No. 4, 41-11 (1959) April. Translation Available from Henry Brutcher, Technical Translations, P. O. Box 157, Altadena, Calif.

Effects of thermal treatment on the corrosion resistance of 1X18H9T in argon arc-welded seams were analyzed. Specimens were quenched in water at 1050 C and stabilized at 850 C for 3 hours, then cooled in air. Comparisons were made with standard untreated specimens. Tests were made in boiling solutions of 57% nitric acid for 200 hours with solution changes after 100 hours. Results showed that thermal treatments lowered the corrosion resistance. Concentrated inter-crystalline corrosion was observed along the welded seams, with the deepest corrosion after repeated short-period heating at 650 C (2 hours). An increased corrosion rate was found in titanium-stabilized seams in acid oxidizing solutions; however, titanium stabilized and non-stabilized seams show the same intercrystalline corrosion after repeated, short-period heating.—NSA. 18389

3.8 Miscellaneous Principles

3.8.2, 6.4.4

Anodic Dissolution of Magnesium Alloys in Aqueous Salt Solutions. R. Glicksman. RCA Lab., Radio Corp. of America. J. Electrochem. Soc., **106,** No. 2, 83-88 (1959) Feb.

The anodic dissolution of a magnesium AZ10A alloy has been studied by measuring corrosion rates and electrode potentials as functions of current density, pH and electrolyte concentration. Results are interpreted in terms of a rate-controlling proton transfer step through a surface film of magnesium oxide and/or hydroxide.

The effect of different alloy compositions and soluble metal additives to the electrolyte on the anodic corrosion rate and electrode potential also has been measured. 17756

3.8.2, 6.3.11

Electrochemical Mechanisms of Noble-Metal/Hydrogen Systems. Part I. Platinum. S. Schuldiner. Naval Research Lab. Project Nos. NR-475-000 and NS-677-100, Dec. 20, 1957, 38 pp. Available from Naval Research Lab., Washington, D. C.

This report is the first of a series reviewing the experimental and theoretical findings of the electrochemical mechanisms of noble-metal/hydrogen systems. The kinetic equations of hydrogen-producing reactions are derived; experimental techniques are discussed, including the use of an electronic current interrupter developed at this Laboratory; and results from studies of the electrode mechanisms of platinum are reported. (auth)—NSA. 18001

3.8.2, 3.6.5, 6.3.11, 3.8.3

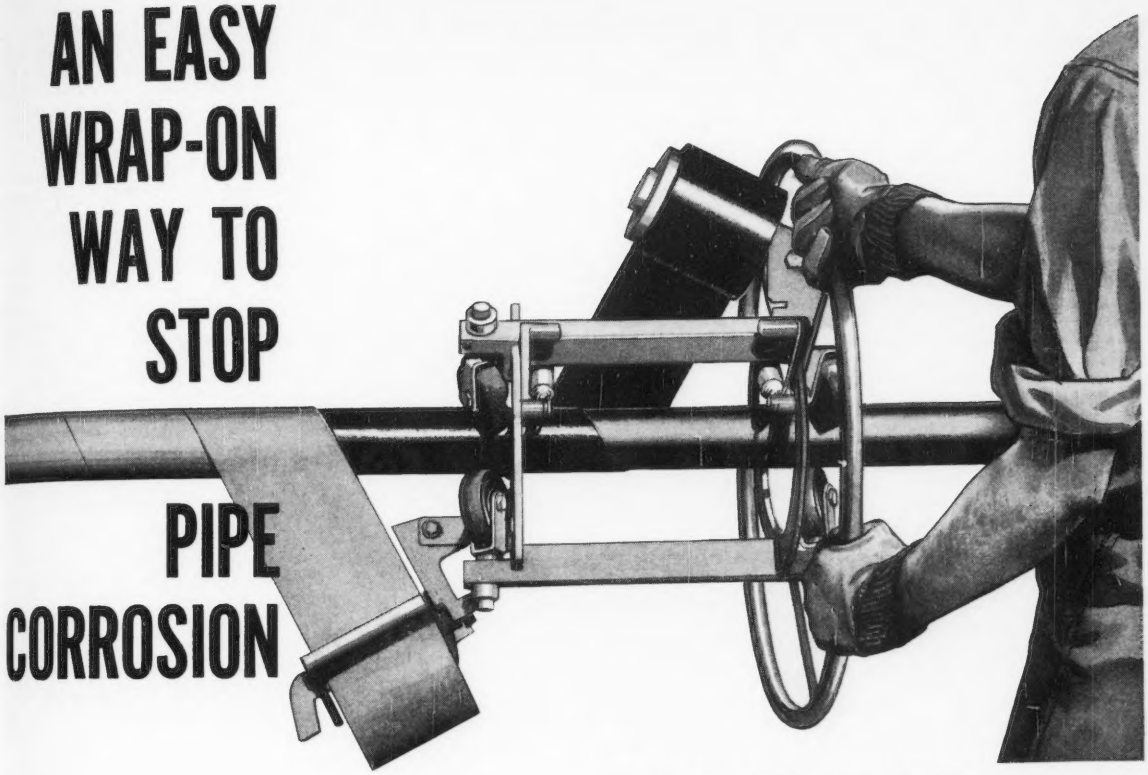
Electrochemical Behavior of Palladium: Potential/pH Diagrams for the Palladium-Water System at 25 C. (In French.) N. de Zoubov, J. van Muylder and M. Pourbaix. Centre Belge Étude Corrosion, Rapport Technique, No. 60, 1-12 (1957); Chem. Absts., **52,** No. 21, 1812-1813 (1958) Nov. 10.

By use of known methods and conventions together with available thermodynamic data, a potential/pH diagram is constructed which summarizes the electrochemical behavior of palladium in water at 25 C. Another potential/pH diagram presents the theoretical conditions of passivation, corrosion and immunity to corrosion. Conditions for the use of palladium as an electrode to measure pH are discussed. The standard free-energy of formation for the oxide, PdO_3 is calculated to be 24 kcal/mole.—MA. 17857

3.8.2, 3.6.5, 6.2.2, 4.4.2

Adsorption From Solution of Stearic Acid on Iron; Effect on Electrode Potential. J. J. Bordeaux and N. Hacker-

AN EASY WRAP-ON WAY TO STOP PIPE CORROSION



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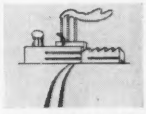

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man. J. Phys. Chem., **61,** No. 10, 1323-1327 (1957).

Adsorption isotherms for both total and irreversible sorption were obtained at room temperature for the system: metallic iron in 80% ethanol/water solutions of stearic acid. The isotherms were determined using carbon "tagged" stearic acid. The effect of non-radioactive stearic acid on the steady state potential of iron was determined also. Experiments were generally run in air-free systems. In these cases the potential became more noble by about 100 mv, depending somewhat on the temperature, being greater at higher temperatures. Essentially all of the potential changes occur before 70% of monolayer coverage is achieved. In the presence of oxygen also the potential change was 2-3 times as great for equal stearic acid concentrations. Application of small amounts of current show that the stearic acid polarizes both the cathodic and the anodic reactions, the former to a slightly greater extent.—RPI. 17869

5. PREVENTIVE MEASURES

5.3 Metallic Coatings

5.3.2

Remote Protection by Sprayed Metal Coatings on Steel. (In German.) Harald Spindler. Werkstoffe u. Korrosion, **9,** No. 5, 278-283 (1958).

Metal coatings—zinc, aluminum and aluminum-5% magnesium alloy—were sprayed on to selected areas of steel samples, and the protection afforded to the bare steel was studied and its extent measured by static and dynamic tests in natural and synthetic sea-water. In alternating-immersion tests, remote protection was given only by zinc. A critical covered to uncovered area ratio is operative.—MA. 17746

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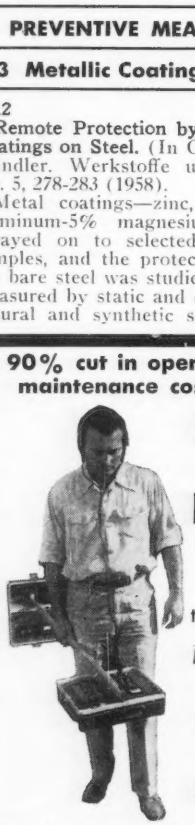

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5.3.4

Antimony Plating on Steel and Zinc. G. R. Schaer, W. H. Safranek and C. L. Faust. Plating, **45,** No. 2, 139-143 (1958).

Anodic treatment of steel in acid solution (preferably phosphoric acid) or iron plating was necessary before continuous, adherent antimony deposits could be obtained from the citrate bath. The former improved the corrosion-resistance of antimony-plated steel but not that of zinc-plated steel. In salt-spray mist and in air saturated with water vapor, antimony-plated steel showed a superior resistance to corrosion than zinc-plated steel. Electroplating antimony on copper-plated or zinc die-castings is not recommended owing to blistering or peeling. The thinner antimony coatings produced on zinc by simple immersion in the citrate bath showed promise as an alternative to chromate coatings under outdoor-exposure conditions.—MA. 17729

5.3.4

New Process for Plating on Light Metals. J. V. Sheridan. Light Metals Plating Co. Products Finishing, **23,** No. 2, 46-47 (1958) Nov.

The Cooper process, a new method of electroplating metals on aluminum and magnesium makes it possible to co-deposit, at small amount of titanium with zinc on aluminum. Although other metals also may be deposited, this combination is the one that shows most promise. It combines excellent properties of adhesion and corrosion resistance in hot atmospheres. Aluminum products requiring a hard chromium surface can be plated readily by the combination of a zinc-titanium co-deposit on the aluminum followed by standard chromium plating on the zinc-titanium layer. This combination provides corrosion resistance as well as the wear resistance of a chromium surface. Process was developed by Carl Cooper of Grass Lake, Michigan.—INCO. 17701

5.3.4, 5.9.1

Present Position of Electroplating. (In German.) Willibald Machu. Stahl u. Eisen, **77,** No. 20, 1374-1383 (1957).

A general review. Aspects dealt with include: addition of wetting agents to alkaline degreasing baths; relative merits of anodic and cathodic methods of electrolytic degreasing; ultrasonics in cleaning and plating; means of improving pickling; chemical and electrolytic polishing; barrel finishing; improvement of nickel-plate corrosion-resistance by polishing; bright aluminum as a substitute for chromium plate.—MA. 17940

5.3.4, 5.9.3, 6.2.2

A New Process for Hot-Tinning Cast Iron. (In French.) C. J. Thwaites. Metaux-Corrosion-Ind., **33,** No. 395/396, 335-342 (1958).

A comparison is made between the T.R.I. direct chloride process (Metallurgia, **56,** 263, 1957) and other hot-tinning procedures. Mircrographs show the effectiveness of iron-grit shot-blasting in removing surface graphite, and the continuity of the coating. Recent extensive bond-strength tests on grey iron give an average value of 3 ton/in.^{2}.—MA. 17611

5.3.4, 4.2.7

Sprayed Electrolytic Zinc Coatings. R. Bourcelot. Metal Industry (London). **93,** No. 22, 453-454 (1958).

French practice is reviewed. Particularly for service in tropical countries, sprayed electrolytic zinc (99.99% pure) may be followed by chromium trioxide treatment and if necessary a synthetic resin.—RPI. 17942

5.3.4

Plasma-Arc Plating. New Production Process for High-Temperature Design. R. D. Stackhouse, A. E. Guidotti and D. M. Yenni. Product Eng., **29,** No. 50, 104-106 (1958) Dec. 8.

Presents first data on coating properties and design parameters for plasma-arc torch method of applying coatings from ultrahigh melting point materials. Operation of plasma-arc torch is described. Ten basic coatings have been established so far: tantalum, palladium, platinum, molybdenum, tungsten, alumina, zirconium diboride and three combinations of tungsten with additives (zirconia, alumina and chromium). Table summarizes density, Vickers hardness, rupture modulus and elastic modulus for tungsten, tungsten-chromium and tungsten ¼ zirconium dioxide.—INCO. 18020

5.3.4

Metallic Anticorrosive Coatings for Steel Structures. (In Dutch.) J. F. H. van Eijnsbergen. Bedriff en Techniek, **12,** 346-350 (1957) May 18.

Structure and behavior of metal coatings in different media. Methods of application, especially by hot spraying and by diffusion of zinc, aluminum, and cadmium coatings.—BTR. 17990

5.3.4

Titanium Coating. Pt. II. Titanium Coating by Fused-Salt Electrolysis. (In Japanese.) Yoshiki Ogawa, Yoshihiro Hisamatsu, Kazutaka Kawamura and Junji Tatsuma. J. Japan Inst. Metals (Nippon Kinzoku Gakkai-Si), **21,** No. 10, 599-602 (1957).

A mixture of potassium fluotitanate, potassium chloride and sodium chloride is electrolyzed under an inert atmosphere. Better titanium coatings were obtained with modulated D.C. than with plain D.C. Vickers microhardness and corrosion-resistance were compared with those obtained by the pyrosol method (loc. cit.).—MA. 17864

5.3.4, 6.2.2

Hot Dip Galvanizing of Grey Cast Iron. (In German.) P. Debouté. Werkstoffe u. Korrosion, **10,** No. 3, 148-151 (1959) March. English Translation Available Free on Request.

This paper was presented at the second congress of the European Federation of Corrosion at Frankfurt in June, 1958.

A process is described for obtaining flawless zinc coatings, 600-900 g/sq.m. on sand-blasted cast iron, using a dipping time of 2-3 minutes at 450°. Complete mechanical cleaning of the surface is necessary. The structure of the zinc coating is discussed and also the reasons why faulty coatings are sometimes obtained. 1 figure, 2 tables.—ZDA. 18310

5.3.4, 8.4.5

Electroclad Aluminum on Uranium. John G. Beach and Charles L. Faust. Battelle Memorial Inst. J. Electrochem. Soc., **106,** 654-659 (1959) August.

Electroplating of aluminum was studied at Battelle in 1953-55 as an alternative method for aluminum cladding of uranium fuel elements. Uranium electroclad with 12 mils of aluminum over a 0.5-mil nickel or nickel-plus-copper

electroplate resisted corrosion for more than 100 hr in boiling water. Hot pressing the electroclad composite improved the corrosion resistance. Many of the results obtained with aluminum electrocladdings paralleled those obtained with wrought aluminum claddings on uranium. (auth)—NSA. 18329

5.3.4, 3.7.4

Effects of Chloride on the Orientation of Nickel Deposits. B. C. Banerjee and A. Goswami. J. Electrochem. Soc., **106**, No. 7, 590-592 (1959) July.

Study of effects of chloride ions in nickel bath shows that chloride ions generally counterbalance outgrowth condition due to impurities and favor lateral growth. This is attributed to desorption of impurities from cathode, which facilitates electron-transfer process. 19 references.—INCO. 18327

5.3.4, 6.2.5

Nitration Effects on Stainless Steel Corrosion Resistance. (In Russian.) A. G. Andreeva and L. Ya. Gurevich. Metalloved. i Termich. Obrabotka Metallov., No. 4, 34-40 (1959) April. Translation Available from: Henry Brutcher, Technical Translations, P. O. Box 157, Altadena, California.

Electrode potentials of 4X14H2B2 (0.42 percent carbon, 13.75 percent chromium, 12.6 percent nickel, 1.5 percent tungsten, 0.5 percent molybdenum, 0.4 percent silicon and 0.7 percent manganese) and 4X14H2B2 (0.4 percent carbon, 13.5 percent chromium, 2.68 percent nickel, 2 percent tungsten, 0.55 percent silicon, and 0.55 percent manganese) in 0.01 N of sodium chloride solution were investigated. The 4X14H-14B2M steel was nitrated at 560 C for 48 hours; ammonium dissociation was 25 to 35 percent. The 4X14H2B2 was nitrated at 600 C for 24 hrs. The changes in nitrated steel corrosion resistance, depending on the depth of the layer, corresponds to the changes in the electrode potential. The layers with low corrosion resistance and lowered electrode potentials, found at a certain depth of nitrated steels, were composed of chromium nitrides and solid solutions, impoverished by chromium and nitrogen.—NSA. 18325

5.4 Non-Metallic Coatings and Paints

5.4.5, 6.2.3

Paints for Structural Steel. W. J. Bradley. American Paint Journal, 43, No. 18, 70+4pp. (1959).

The type of shopcoat primer must be considered, with the type and degree of surface preparation. No single type of painting system can be recommended as being outstanding in meeting all the specific properties and requirements.—RPI. 17750

5.4.5, 3.4.8

Investigation of Anticorrosive Properties of Surface Coatings for Equipment Used to Remove Hydrogen Sulphide from Gas by Means of Sodium Arsenate. (In Russian.) G. A. Isayov and Y. D. Gazovaya Prom., No. 7, 21-23 (1957); Chem. Absts., 52, No. 5, 4208d (1958) March 10.

A number of coatings are discussed, such as lacquers and resins, which are referred to only by their Soviet trade names. The best material found for coating the inside iron scrubbers was a resin with a ferric oxide filler.—RPI. 17952

5.4.5

Solvent-Free Epoxy/Amine Combinations in Surface Protection. (In German.) H. Zumstein. Fette, Seifen, Anstrich, 60, No. 7, 547-552 (1958).

The film properties of epoxy/polyamide resin combinations cured with polyamines, usually in the cold, but also at high temperatures, are reported. The amines are characterized by possession of tertiary amino and at least one phenolic, groups. Alternatively, triethylene-tetramine was used. Epoxy resins of viscosity 100 poises in combination with polyamide resins provide soft films, other film properties being substantially unchanged; addition of solvent of an epoxy resin so employed to reduce its initially higher viscosity to the same value, results in cured films which are hard but susceptible to solvent attack. Fields of application, e.g., in primers and protective coatings generally, with typical formulations are given.—RPI. 17673

5.4.5

Protective Coatings. Part II. Francis Scofield. National Paint, Varnish and Lacquer Association. Ind. and Eng. Chem., **50** No. 9, 1479-1481 (1958) Sept.

Recently, great emphasis has been placed on relatively new materials as binders for coatings, the greatest interest being in epoxy resins. Other coatings of interest are polyurethanes, various elastomers and polyesters. A review of the properties and uses of these and various other new coatings is presented.—NSA. 17646

5.4.5

Anti-Corrosive Coatings for Marine Applications. R. E. T. Hanson and W. P. Jenkins. Corrosion Prevention & Control, **4**, No. 6, 45-46 (1957) June.

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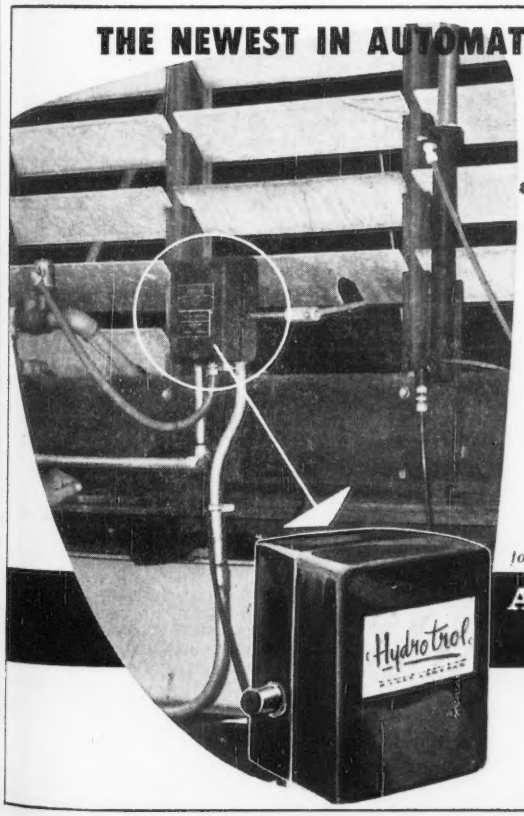

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Discusses importance of surface preparation, selection of proper priming paint and recent developments in surface coatings. Of coatings based on vinylidene chloride-acrylonitrile resins, isocynate resins and epoxy resins, the latter hold greatest promise. Catalyzed liquid snythetic rubber coatings have excellent resistance to all types of petroleum, jet fuels, kerosene and salt water.—INCO. 17873

5.4.7

Spray- and Brush-Applied Neoprene Coatings. P. G. Blackburn. Corrosion Technology, **6,** No. 3, 77-78 (1959) March.

Where vessels are too complex or inaccessible for lining with sheet neoprene, application by spray or brush can now be carried out, to protect new or used equipment. Applications for this form of protection, ranging from acid agitators to marine propellers and rudders, are surveyed.—RPI. 18318

5.4.8, 5.4.7

Properties and Uses of Catalytic Coatings. J. F. Howe. Products Finishing, **23,** No. 1, 45-47 (1958).

Catalytic protective coatings (combinations of vehicles, catalysts and rust-inhibitive pigments) provide a combination of chemical treatment and anti-corrosive paint coating in one application. The coatings are characterized by excellent resistance to salt water, moisture or humidity, acids and gaseous fumes and by superior durability, adhesion, speed of dry and wetting properties. The coatings may be applied by brush, spray, roller-coat, dip, electrostatic spray and flow-coat methods and are useful where acid- and corrosion-resistant coatings are required. Several case histories illustrating various applications of catalytic coatings are mentioned.—RPI. 18131

5.4.8, 3.3.4

Science for the Coatings Technologist. Pt. XII.—Paint Additives—Mildewcides (Metallic Compounds as Additives) (1, 2). E. S. Beck. Metal Finishing, **57,** Nos. 1, 2; 54-57; 65-68, 75 (1959).

(1). The extent of the problem of the growth of micro-organisms in paint packages and films is discussed. Formulation modifications tend to have other unfavorable effects and additives must be used. The most common are mercury copper and phenolic compounds. (2) The uses of these compounds as fungicides are described.—MA. 18245

5.4.8

Silicone Resins in Surface Coatings. D. R. Goddard and E. A. Mason. Paint Manufacture, **29,** 155+4 pp. (1959) May.

Resistance to heat, chemicals and weathering exhibited by silicone resins can be acquired by paints in which they are incorporated. Selection of suitable resins, pigments and driers is essential to obtain the best results.—BTR. 18314

5.8 Inhibitors and Passivators

5.8.1, 6.2.3, 6.2.2, 3.2.3

Effect of Inhibitors of the Corrosion of Iron on the Air-Formed Film. P. Hancock and J. E. O. Mayne. J. Chem. Soc., (London), **1958,** 4172-4175, Nov.

Effect of 0.1 N sodium benzoate, acetate, borate, carbonate and hydroxide on the air-formed film on pickled mild steel, pickled or hydrogen reduced iron, was determined electrometrically. The film was reinforced and thickened by material of similar composition by 20-120 percent, depending on the inhibitor and surface condition.—EL. 18177

5.8.1, 4.3.2

Effect of Urotropin on Corrosion of Steel. (In Ukrainian.) A. S. Afanas'ev, A. P. Brynza and L. I. Gerashutina. Ukrainskii Khimicheskii Zhurnal, Akademii Nauk Urainskoi SSR, **25,** 73-80 (1959) Jan.

Urotropin (hexa-methylene-tetramine) in weak concentrations is an anodic inhibitor of acid corrosion, while in strong concentrations it stimulates corrosion. Corrosion losses in 0.2N sulfuric acid of an oxidized and scale-covered steel were considerably decreased by the use of urotropin as an acid inhibitor. 8 references.—RML. 18238

5.8.1, 6.2.2

Effects of Inhibitors on Iron Corrosion. H. Grubitsch and T. Sneck. In French: Corrosion et Anticorrosion, **7,** No. 4, 153-161 (1959) April; In German: Teknillisen Kemian Aikakauslihti (Helsinki), **16,** 203-216 (1959) April.

Urotropine acts as an anodic inhibitor in neutral solution and as a cathodic inhibitor in acid solution. Ethyl quinoline iodide scarcely acts in a neutral medium, but is a powerful anodic inhibitor in an acid medium and to a lesser degree a cathodic inhibitor. In each case studied, the inhibiting anodic effect rests on a decrease of the strength of the local current.—BTR. 18294

5.8.3, 6.2.2

Inhibition of the Corrosion of Iron in Neutral and Alkaline Solutions. Pt. I. P. Hancock and J. E. O. Mayne. J. Applied Chem., **9,** Pt. 7, 345-352 (1959) July.

Potentials at which iron is converted into anhydrous cubic oxide in certain inhibitive solutions were measured and it is shown that these potentials are more negative than potentials acquired by unpolarized specimens immersed in solutions for 3 days. It is suggested that when iron, carrying its air-formed film, is placed in an inhibitive solution, saturated with air, corrosion current is concentrated at weak spots in oxide film and at these points potential is consequently raised to that at which anhydrous cubic oxide is produced, air-formed film is thereby thickened and corrosion prevented. When pH of inhibitive solution exceeds 9, anhydrous cubic oxide may also be formed by interaction of anodic product, ferrous hydroxide, with atmospheric oxygen. This explanation of inhibition has been extended to account for corrosive nature of pure water, effect of concentration of inhibitor, dual role of oxygen and effect of oxygen on efficiency of non-oxidizing inhibitors. Tables, graphs, 17 references. —INCO. 18249

5.8.3, 5.8.4, 2.3.9

Effect of Ions on the Protective Action of Phosphate Corrosion Inhibitors. N. G. Chen. J. Applied Chem., USSR (Zhur. Priklad. Khim.), **32,** No. 7, 1523-1528 (1959). English Translation of Journal Available from Consultants Bureau, Inc., 227 West 17th Street, New York 11, New York.

Study using radioactive tracers demonstrated the importance of adsorption in the action of inhibitors. 5 tables, 4 references.—ATS. 18304

5.8.4

Protective Action of Corrosion Inhibitor Mixtures in Neutral Atmospheres. (In Russian.) A. S. Afans'ev and F. V. Zhuk. J. Applied Chem. (Zhur. Priklad. Khim.), **32,** 141-149 (1959) Jan. English Translation of Journal Available from Consultants Bureau, Inc., 227 West 17th Street, New York 11, New York.

Effects on atmospheric and underwater corrosion of steel of sodium nitrite, silicon-nitride; triethylamine, sodium triphosphate, emulsions used as corrosion inhibitors. 4 references.—RML. 18206

5.8.4, 6.2.2

New Investigations in the Field of Vapor Phase Inhibitors. (In German.) Leo Cavallaro and Giorgio Mantovani. Werkstoffe u. Korrosion, **10,** 422-425 (1959) July.

Protection of cast iron surfaces; data on film forming and acid neutralizing inhibitors such as morpholin ethylamine octadecylamine dicyclohexylammonium-nitrite and sodium benzoate.—RML. 18302

5.8.4, 4.6.5, 4.6.6

Sodium Salicylate as a Corrosion Inhibitor in Neutral Media. (In Russian.) E. V. Bogatyreva and S. A. Balezin. J. Applied Chem., USSR (Zhur. Priklad. Khim.), **32,** 1071-1076 (1959) May. English Translation of Journal Available from Consultants Bureau, Inc., 227 West 17th Street, New York 11, New York.

$NaC_7H_5O_3$ retards corrosion in distilled and tap water for many steels. Minimum protective concentrations are given together with optimum temperatures. 7 references.—RML. 18220

5.8.4, 6.3.19

Chromic Acid Passivation of Zinc with the Chromic Acid Ester of Tertiary Butyl Alcohol. L. Cerveny. Coll. Czech. Chem. Communications, **24,** 1400-1407 (1959) May. (In German.)

Samples of galvanized steel sheet exposed to vapors of the passivation agent under reduced air pressure. Corrosion resistance depends on the time the samples are exposed to the agent. 24 references.—RML. 18336

5.9 Surface Treatment

5.9.4, 6.3.8, 3.8.4

Anodic Oxides of Lead. Jeanne Burbank. J. Electrochem. Soc., **106,** No. 5, 369-376 (1959).

After anodizing pure lead at constant anode potential in solutions with pH varying from —0.63 to 14.5, the resultant oxides were identified by X-ray and electron diffraction. Areas of occurrence of α- and β-lead dioxide, red and yellow lead monoxide and PbO_x ($1.5 \leqslant X \leqslant 1.6$) were determined as functions of pH and potential. The intermediate oxides PbO_x are not direct anodic oxides, but are formed as a result of chemical actions. It is also shown that α-lead dioxide is the low-temperature form and is converted to β at ~300 C. 50 references. —MA. 18276

5.9.4.

Chromate and Phosphate Treatments for Corrosion Protection. Pt. 1. D. J. Fishlock. Corrosion Prevention & Control, **6,** No. 8, 42-46, 51 (1959) Aug.

Discusses general principles of chromate and phosphate coatings, their characteristics and properties and reviews the many treatments developed for zinc, tin-zinc, copper-base alloys, tin, silver, chromium, magnesium, aluminum, steel

and stainless steel. Among processes covered are: Cronak, Iridite, Atram OS, Protecta-Tin, Tridur, RAE, M.E.L., Dow 17, New Chrome and Alocrom. Solution compositions and application conditions are given.—INCO. 18296

5.9.4

Crystalline and Amorphous Phosphating. (In French.) A. Bayon. Corrosion et Anticorrosion, **7,** No. 3, 110-113 (1959).

Crystalline phosphating gives a crystalline coating (~50μ) and a weight-increase; amorphous phosphating (passivation) involves surface transformation, with formation of very thin (~0.5μ) films and practically no weight-increase. Advantages of each, and the composition and behaviors of the agents used, are presented and discussed.—MA. 18316

5.9.4

Hard Anodizing of Aircraft Fuel-Metering Components. Harold J. Wiesner and Henry A. Meers. Tech. Proc. Amer. Electroplaters' Soc., **45,** 105-117; disc., 166-168 (1958).

Production of both thin and heavy anodized coats on the same component is described; heavy anodizing baths are based on sulfuric acid and oxalic acid, the thin coating baths on nickel acetate, but thickness on components of unknown area is controlled by the use of a parallel circuit anodizing a standard bar. Quality control is based on coat thickness, hardness and surface finish; methods for thickness determinations are compared. The required operating voltage is increased by higher sulfuric acid concentration and lower bath temperature. High-copper alloys are coated in a solution containing 385 g/l sulfuric acid and 11-15 g/l oxalic acid at < 50 F. (10 C.). 10 references.—MA. 18129

5.9.4, 6.4.2, 5.3.4

Hard Anodize, Hard Chrome on Aluminium. Myron Miller and Bill J. Fullmer. Western Metalworking, **16,** No. 8, 21-24 (1958).

Hard anodizing process described is the application of a relatively thick, hard aluminum oxide surface on aluminum. Thickness varies from 0.5 to 4.0 mils. The "hard-chrome" process consists of two methods; (1) bonding chromium by a mechanical interlocking effect on aluminum previously roughened by etching or made porous by anodizing under special conditions, and (2) cleaning base metal, followed by hard-chromium plating either over intermediate coatings or direct on to the base metal. Zinc immersion is often used to give the intermediate coating. New processes based on these principles are described and illustrated.—MA. 18138

5.9.4

A New Method of Phosphating Metals. D. Drazic. Zastita Materipala, **7,** No. 1, 28-29 (1959) Jan.

Author discusses recently developed methods of phosphating which are more rapid and employ the lowest possible temperatures. The processes are electrolytic, using either alternating or direct current. Several modifications of phosphate solutions are given together with the temperatures employed, currents, and times of running. One method for phosphating in the cold uses zinc nitrate 30 g/l with manganese phosphate, sodium fluoride and sufficient zinc oxide to give a pH of 3.1. Current density is 1-1.5 amp/dm² at 12 volts for 20 minutes.—ZDA. 18262

5.9.4, 6.3.19

Anodic Oxidation of Zinc and a Method of Altering the Characteristics of the Anodic Films. H. Fry and Marjorie Whitaker. British Non-Ferrous Metals Research Assoc. J. Electrochem. Soc., **106,** 606-611 (1959) July.

Preliminary work on anodizing zinc in a variety of alkaline solutions led to some smooth white or gray films. A detailed study was made of the anodic oxidation of zinc and zinc alloys in one electrolyte the results of which suggest similarities but also some differences between anodic films on aluminum and on zinc. Autoclaving in silicate solutions improved the resistance to corrosion and abrasion and changed the chemical composition of the anodic films without altering their appearance greatly. 18313

6. MATERIALS OF CONSTRUCTION

6.2 Ferrous Metals and Alloys

6.2.2

Selection of Alloys for Corrosion Resistant Service. W. T. Bryan. Metal Progress, **74,** No. 6, 102-105 (1958) Dec.

Factors that should be considered in the selection of alloys for corrosion-resistant service are discussed. Characteristics of the corrosive environment, mechanical properties and metallurgical structure are some of the factors that are considered. The discussions are lim-

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ited mostly to the performance of iron-chromium, iron-chromium-nickel, and iron-chromium-molybdenum alloys in corrosion-resistant service.—NSA. 18023

6.2.4, 3.5.9, 3.2.2, 3.7.3

Study of Ductile-Brittle Transition Temperature of Some Low-Alloy Steels. (In Russian.) A. P. Sanina and M. M. Timofeev. Metalloved. I Obrabotka Metallov, No. 8, 57-58 (1958) August. Translation Available from Henry Brutcher, Technical Translations, P.O. Box 57, Altadena, Calif.

Search for inexpensive structural steel resistant to embrittlement at subzero temperatures. Steel compositions tested and compositions recommended for use. Effect of heat treating subsequent to hot working, and of phosphorus content (0.015 to 0.05 percent phosphorus) upon critical transition temperature. Results of tests for weldability; data on electrodes best suited; particulars on coating composition; impact strengths of welds, after welding and after straining at various subzero temperatures, followed in part by tempering. 3 figures. —HB. 17776

6.2.5, 8.4.3, 3.2.2

Plant Corrosion Test of Stainless Steel on Petroleum Refining Unit. (In Japanese.) Yahiko Kadono. Corrosion Engineering, **8,** No. 2, 7-9 (1959) Feb.

Plant corrosion tests of stainless steel were performed in a petroleum refining unit. The results showed:

1. Poor corrosion resistance of 4-6 chromium steel.

2. 13 chromium steel & 18-8 chromium-nickel steel withstand almost all the environments encountered in the refining unit.

3. The environments favorable to pitting corrosion of stainless steels were investigated.

4. AISI Type 316 stainless steel offers the least resistance to pitting corrosion. 17634

6.2.2, 3.2.3, 4.6.2, 3.5.9, 3.7.2

Growth and Scaling Characteristics of Cast Irons in Air and Steam. G. N. J. Gilbert. Britist Cast Iron Research Assoc., Res. Rept. No. 502. J. Res. & Dev., B.C.I.R.A., **7,** No. 10, 478-566 (1959) Feb.

Growth and scaling results in air at temperatures up to 500 C for periods up to 64 weeks, and in steam at temperatures up 427 C for periods up to 49 weeks, are reported for 35 cast irons. These included flake graphite cast irons (some containing nickel), nodular graphite cast irons (nickel containing) and a blackheart malleable cast iron. Tensile and hardness tests were also carried out on specimens subjected to growth tests. Results show that cast iron is structurally stable and not subject to growth at temperatures up to 400 C in air and steam for periods of test. It appears from results that present limiting temperatures of 232 C for cast iron in steam applications is too low and 343 C appears to be more realistic temperature. Short-time high-temperature tensile results on all materials are given to supplement growth data. Influence of alloying elements in flake graphite irons (carbon, manganese, sulfur, phosphorus, chromium, nickel, molybdenum, tin and arsenic) and in nodular irons (silicon, chromium, molybdenum, tin, copper, arsenic, tungsten, vanadium and boron) on growth, scaling and mechanical properties is covered. Tables, graphs.—INCO. 17715

6.2.2, 4.3.2, 3.8.4

Adsorption of Hydrogen in the Dissolution of Iron. (In German.) L. Cavallaro, G. P. Bolognesi and L. Felloni. Werkstoffe u. Korrosion, **10,** 81-86 (1959) February.

Results from Armco iron sheet samples dissolved in hydrochloric acid indicate a correlation between the quality of hydrogen adsorbed from the iron and the dissolution speed. 10 references.—RML. 18328

6.2.2, 4.3.3, 3.7.2

High-Temperature Corrosion of Metals by Vanadium Oxide. Pt. 5. Mechanical Properties and Behavior of Iron-Aluminum-Titanium Alloys. (In Italian.) A. Burdese and S. Gallo. Metallurgia Italiana, **51,** 65-71 (1959) Feb.

Effect of increasing aluminum content on oxidation resistance of iron in presence of vanadium pentoxide vapors. Properties compared with those of commercial superalloys, particularly the refractory "Thermenol." Addition of small quantities of titanium and carbon to iron-aluminum alloys simplifies their manufacture and decreases costs, improves forgeability and mechanical properties and produces a finer grain than molybdenum additions. Titanium is partially segregated as a carbide. 24 references.—RML. 18257

6.2.5, 3.7.2

New Stainless Better Than Type 316. R. B. Norden. Chem. Eng., **65,** No. 25, 194, 196 (1958) Dec. 15.

Improved stainless, AISI D319, with superior corrosion resistance is strongly bidding to replace Type 316 in chemical process equipment. New composition has 17.50-19.50 chromium, 11.00-15.00 nickel and 2.25-3.00 molybdenum; increased chromium and nickel contents insure better over-all corrosion resistance and increasing minimum content of molybdenum boosts corrosion resistance to acids. This composition has been approved by ASME Boiler and Pressure Vessel Committee for direct replacement of Type 316.—INCO. 17504

6.2.5, 8.9.1, 5.4.8

Corrosion Prevention for Polaris. H. C. Slaughter. Lockheed Missile Systems Div., Astronautics, **3,** No. 12, 38-39, 64-66, 68, 70 (1958) Dec.

Special protective finishes, corrosion-resistant materials and encapsulation provide capability for withstanding extended periods of constant readiness during storage or stowage of Polaris without deterioration. An example of the use of a more unique material to combat corrosion under circumstances demanding excellent high-strength properties is the precipitation hardened AM 350 stainless steel pressure vessel. In addition to excellent fabricating and mechanical properties, it displays corrosion-resistance in the hardened condition approaching that of conventional 18-8 stainless materials. Potting and embedding compounds and resins, plus moisture and fungus resistant coatings, are used to prevent corrosive deterioration of electrical and electronic wiring, circuitry and components. Photos.—INCO. 17743

6.2.5, 3.7.3, 8.4.5

Welding of Stainless Steel which Contains More than 1% Boron. Nicholas Balai. Minutes of the Seventh Annual Atomic Energy Commission Welding Conference, Chicago, Illinois, Nov. 6-8, 1957. Argonne National Lab., U. S. Atomic Energy Comm. Pubn. TID-7562 (p. 15-31), 1957, 17 pp. Available from Argonne National Laboratory, P. O. Box 299, Lemont, Illinois.

Properties of high-boron stainless steels, cast and wrought, are summarized, and welding of these materials is discussed. The fabrication of experimental control rod sections, Experimental Boiling Water Reactor control rods, Experimental Boiling Water Reactor pressure vessel thermal shield and fuel storage rack from this material is described. Corrosion and irradiation test data are given.—NSA. 17867

6.3 Non-Ferrous Metals and Alloys—Heavy

6.3.11, 3.7.4, 3.7.2

Grain Size and Age-Hardening of Gold-Platinum Alloys. H. Schmid. Metall, **12,** No. 7, 612-619 (1958); Platinum Metals Rev., **2,** No. 4, 135 (1958) Oct.

Effect of rhodium on grain size and age-hardening of gold-platinum alloys for use as spinnerets in the rayon industry was investigated. Following alloys were considered: 25 platinum-gold, 30 platinum-gold, 50 platinum-gold, 0.5 rhodium-25 platinum-gold, 0.5 rhodium-30 platinum-gold and 1 rhodium-49 platinum-gold. Alloys with 25-50 platinum, after severe cold deformation and annealing at 1000 C for 14 hours, still exhibit grain segregation, the platinum-rich phase occurring with a dendritic structure. Grain size of alloy depends on the distance between these dendrites. Rhodium additions are not necessary to a fine grained structure, which is dependent only on the correct choice of cooling conditions leading to a heterogeneous structure when cast. Hardness increases to a maximum with tempering time and then falls. In the heterogeneous alloys, which are those used in spinneret manufacture, rhodium-free alloys reach a higher maximum hardness than rhodium-containing alloys, with the exception of the 25 platinum alloy. In the homogeneous state, the 0.5 rhodium-25 platinum alloy is considerably harder than the binary alloy and the 0.5 rhodium-30 platinum alloy has about equal hardness. The 1 rhodium-40 platinum alloy cannot be obtained in a homogeneous form. Tensile strength behaves in an analogous way to hardness.—INCO. 17737

6.3.13, 4.7

Corrosion and Creep Behavior of Tantalum in Flowing Sodium. Gilbert E. Raines, C. Vernon Weaver and John H. Stang. Battelle Memorial Inst. U. S. Atomic Energy Comm. Pubn., BMI-1284, August 21, 1958, 29 pp. Available from Office of Technical Services, Washington, D. C.

Corrosion behavior of commercial tantalum in high-purity flowing sodium from 700 to 1200 F and the effect of sodium exposure on the creep strength of tantalum at 1200 F were investigated. The tests were conducted in forced-convection flow loops constructed of Type 316 stainless steel. With continuously gettered sodium systems (probably containing less than 10 ppm oxygen) operating for periods up to 50 days, weight losses sustained by 1200 F specimens corresponded to only about 0.1 mil of metal removed per year. Maximum weight losses, encountered with a continuously cold-trapped (about 40 ppm

oxygen) sodium system, were equivalent to about 3 mils per year for 1200 F specimens. For the most part, metallographic examinations revealed no deleterious corrosion effects; however, one particular group of arc-cast tubing specimens suffered severe intergranular attack in sodium with about 80 ppm oxygen. In addition to the corrosion findings, the corrosion tests yielded information about the partition of interstitials, particularly oxygen, in the sodium-tantalum system. Oxygen, for example, showed a tendency for migration from tantalum to high-purity sodium considerably stronger than would be predicted from limited thermodynamic data available. In the creep experiments, the oxygen content of the sodium was maintained at the < 10 ppm level by continuous gettering. In general, the results demonstrated that sodium exposure at 1200 F had very little, if any, effect on tantalum creep strength. Baseline data necessary to establish this were obtained in supplementary helium-atmosphere creep tests. (auth)—NSA. 17810

6.3.17, 3.5.4

Corrosion of Irradiated Uranium Alloys. Sherman Greenberg. Argonne National Lab. Nuclear Sci. & Eng., **6**, 159 (1959) Aug.

As a result of heat treatment under irradiation, niobium-uranium-zirconium alloys exhibited corrosion rates at 260 C in initially pure water as low as 1880 mg/cm²/day. Rates are based on original exposed area.—NSA. 18364

6.3.14, 3.6.8, 5.8.1

Effect of Sodium Pyrophospate on Polarization and Corrosion of Tin. I. A. Ammar and S. Riad. Cairo University, Cairo, Egypt. J. Electrochem. Soc., 106, 926-929 (1959) Nov.

Corrosion rates and corrosion potentials have been measured for tin in eight different acid, alkaline and neutral solutions. The corrosion potential, measured against the saturated calomel electrode, has been found to increase toward more active potentials with increase of concentration. It has been observed that sodium pyrophosphate decreases the corrosion rate and increases the corrosion potential toward more active values. This increase is proportional to the amount of pyrophosphate added. Cathodic and anodic polarization measurements have been carried out in an attempt to explain the function of sodium pyrophosphate as a corrosion inhibitor. The results have been compared with previous work on the inhibition of iron corrosion by polyphosphates. 18254

6.3.15, 3.8.4

Oxidation of Titanium Metal and Titanium-Aluminum Alloys. Masao Adachi and Tokuzo Tsujimoto. Trans. Nat'l. Res. Inst. Metals, **1**, No. 1, 32-38 (1959).

Authors determined the oxidation rates of titanium metal and its alloys containing 1-8 percent of aluminum by a quartz-spring balance at a temperature between 907-1041 C, and found that the oxidation rates of this metal and these alloys, except for the alloy containing 1 percent of aluminum, followed the parabolic rate law after 100 minutes oxidation. Oxidation products were examined by a microscope and X-ray photograph. Scales consisted, for the most part of titanium dioxide. The experiments of reoxidation of oxidized specimens showed that the thickness of titanium dioxide was the rate controlling element of oxidation by diffusion mechanism. The experiments by marker showed that titanium ions diffused through titanium dioxide layer from the metal-oxide interface to the oxide-gas interface.—BTR. 18331

6.3.20, 4.6.2, 3.5.4, 3.2.2

Oxidation and Corrosion of Zirconium and Its Alloys. Pt. I. Destructive Internal Oxidation of Zircaloy-2 in Steam Under Irradiation at 300 C. K. Alcock and B. Cox. United Kingdom Atomic Energy Authority. Research Group. Atomic Energy Research Establishment, Harwell, Berks, England, C/R-2826, Feb., 1959, 26 pp. Available from The British Information Service, 45 Rockefeller Plaza, New York, New York.

Destructive localized attack on Zircaloy-2 has been observed and reproduced in steam under irradiation at 300 C in BEPO. Despite visual similarities with the rapid hydriding attack of Zircaloy-2 observed at Chalk River, metallographic examination has failed to reveal any unusual accumulation of hydride in the metal. Possible explanations of this phenomenon are discussed and the future program outlined. (auth)—NSA. 18203

6.3.20, 3.2.2

A Summary of the Work Associated with the Solution and Understanding of Stringer-Type Corrosion in Zircaloy-2 and -3. J. G. Goodwin, L. S. Rubenstein, J. D. Grozier and F. L. Shubert. Westinghouse Electric Corp. U. S. Atomic Energy Commission Pubn., WAPD-212, April, 1959, 24 pp. Available from Office of Technical Services, U. S. Dept. of Commerce, Washington 25, D. C.

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formed to eliminate stringer-type corrosion from Zircaloy-2 and Zircaloy-3. The investigation included a study of the melting and fabrication variables of the alloys. Metallographic and thermal treatment studies identified the problem to be inert atmosphere melting. Based on this work a stringer formation mechanism has been postulated. (auth)—NSA. 18371

6.3.20, 3.4.6, 3.7.3

Properties and Processing of Zirconium and Zirconium Alloys. (In German.) K. Anderko and E. G. Hess. Metall, **13,** 638-643 (1959) July.

A brief review is given of the chemical, physical and mechanical properties of zirconium, Zircaloy-2, and zirconium-niobium alloy. The reaction of the metals and alloys with atmospheric gases and hydrogen is described. The conditions for heat and cold working are discussed. Heat treatment of the metal and alloys is also considered. 11 references.—NSA. 18345

6.4 Non-Ferrous Metals and Alloys—Light

6.4.2, 3.7.2

Effect of Degree of Purity on Properties of Aluminum. (In German.) P. Brenner. Galvanotechnik, **50,** 205-209 (1959) April 15.

Aluminum shows an increase in corrosion resistance in proportion to an increase in its purity. The influence of silicon additions is very small compared with that of copper. Zinc up to 0.4 percent does not affect the corrosion resistance of aluminum. Stress-corrosion of aluminum-zinc-magnesium alloys may be diminished by heat treatment, retarded cooling and additions of chromium and vanadium.—RML. 18212

6.4.2, 4.6.1

Corrosion of 1100 Aluminum in Boiling H_2O and D_2O. J. E. Draley, S. Mori and R. E. Loess. Argonne National Lab. U. S. Atomic Energy Commission Pubn., ANL-6015, July, 1959, 10 pp. Available from Office of Technical Services, U. S. Dept. of Commerce, Washington, D. C.

After an initial exposure period, corrosion rates of 1100 aluminum are approximately the same in water and deuterim oxide at 100 C. More corrosion was observed during the initial exposure period in water, but it is possible that this is only a reflection of the difference in control of the purity of the test water. (auth)—NSA. 18330

6.4.2, 4.6.5, 4.3.6, 2.3.9, 5.8.2

Corrosion and Passivation of Metals as Observed with the Aid of Paper Chromatographic Electrophoresis. (In German.) J. Frasch. Werkstoffe u. Korrosion, **10,** No. 4, 219-226 (1959) April.

Corrosion of aluminum in distilled water, tap water and sodium chloride solution was studied by using the technique of paper chromatographic electrophoresis. Sodium chromate and sodium nitrate added to tap water have a total passivating effect on aluminum, while disodium hydrogen phosphate provides absolute inhibition. Added to a sodium chloride solution sodium chromate is an almost perfect inhibitor, only slightly less effective than di-sodium hydrogen phosphate. Sodium nitrate, on the other hand, seems to further the corrosion of aluminum by salt solution.—ALL. 18295

6.4.2, 1.3

Aluminium and Its Alloys in 1958: Some Aspects of Research and Technical Progress Reported. E. Elliott. Metallurgia, **59,** Nos. 352, 353; 79-85; 109-116 (1959) Feb., Mar.

Attention is drawn to work published in England and the U.S.A. (222 references), reporting research and technical progress during 1958 in the various aspects of the metallurgy of aluminum and its alloys, including extraction, founding, fabrication, constitution, properties and standardization. Reference is also made to interesting applications of these materials.—ALL. 18350

6.4.2, 3.6.6, 3.4.9, 5.8.1, 5.4.5

Corrosion of Aluminum and Its Alloys When in Contact with Non-Metallic Materials. G. FitzGerald-Lee. Corrosion Technology, **6,** No. 6, 185-188 (1959) June. See Also: Automobile Engr., **49,** No. 6, 215-217 (1959) June.

Outlines some guiding rules and principles for preventing effects of corrosion when aluminum is used with wide range of materials, including concrete, cement, plaster, soils, timber, adhesives, mastics and insulating materials. Importance of preventing moisture accumulation is stressed. Advantages of using corrosion inhibitors are reviewed and paint systems for aluminum are discussed.—INCO. 18286

6.4.2, 3.6.6, 4.6.5, 4.6.6, 8.4.5

Behavior of Aluminum Galvanically Coupled to Ferrous Alloys in Water at 200 F. D. C. Belouin. Knolls Atomic Power Lab. U. S. Atomic Energy Commission Pubn., KAPL-M-DCB-3, March, 1959, 16 pp. Available from Office of Technical Services, U. S. Dept. of Commerce, Washington 25, D. C.

Corrosion characteristics of carbon steel, stainless steel and aluminum galvanic couples were examined after eight weeks immersion in deoxygenated, deionized water and in tap water, both at 200 F. These tests were run in an attempt to obtain information pertinent to the SAR fuel element transfer cask design. (auth)—NSA. 18340

6.4.2, 4.6.7, 8.4.3

Aluminum Withstands Corrosive Effects of Maracaibo's Warm, Oxygen-Rich Waters. R. S. Dalrymple. Oil & Gas J., **57,** No. 38, 84-87 (1959) Sept. 14.

Aluminum pipelines and drilling structures of alloys 6061 and 6062 show only minor corrosion from the water line to 30-40 ft. below and are virtually free of attack under this zone and into the mud on the lake bottom. Installations are by Creole Petroleum Corp., Superior Oil Co. of Venezuela, and Signal Oil Co. of Venezuela in Lake Maracaibo, where the water is warm and oxygen-rich. Galvanic couples between aluminum and steel accelerate aluminum corrosion. Unprotected steel liner pipe is seriously corroded in the water but not in the mud. 18359

6.4.4, 5.4.5, 5.9.4

Protection of Magnesium Alloys. W. F. Higgins. Chemistry and Industry, No. 49, 1604-1612 (1958).

General corrosion behavior and methods of protecting magnesium are described. The fluoride-anodized surface makes an excellent paint base. As with most metals, a priming coat is usual and one with leachable chromate is used to reinforce the passivating effect of the chemical chromate film. Meticulous cleaning of surface, especially degreasing, is essential for good results. Other things being equal, stoving paints give better protection than air-drying paints. The thicker the paint film or the greater the number of coats, the better the protection. Magnesium alloys should be painted soon after the surface has been freshly chromated or otherwise prepared. A process is described in which the anodized or chromated magnesium article is dried at 200-220 C, dipped while still warm in an epoxy resin solution, stoved and the process repeated twice more; a primer and finishing system may be applied over this when necessary.—RPI. 18121

6.6 Non-Metallic Materials

6.6.4, 3.5.4, 8.4.5

Oxidation of Graphite During Irradiation in Oxygen. P. C. Davidge, M. Tomlimson and J. Wright. United Kingdom Atomic Energy Authority. Research Group. Atomic Energy Research Establishment, Harwell, Berks, England. AERE-C/R-1450, April, 1959, 81 pp. Available from British Information Service, 45 Rockefeller Plaza, New York, New York.

Apparatus and procedure are described which were used to measure rapidly very low rates of carbon dioxide evolution from samples of reactor graphite oxidizing at 60 to 300 C during irradiation ($\sim 2 \times 10^{12}$ neut cm^{-2} sec^{-1}) in a stream of oxygen in the reactor BEPO. The normal thermal oxidation rate measured outside the reactor, at 300 C, by means of the carbon dioxide produced was equivalent to 0.59 percent weight loss per 1000 days, which agrees with past measurements of weight loss at higher temperatures. There were indications that at this temperature the thermal oxidation rate was enhanced by about 1 order of magnitude as a result of previous irradiation to about 2×10^{19} neut cm^{-2}, either as a direct consequence of radiation damage to the graphite, or as a sequel to other radiation induced reactions. At lower temperatures, thermal oxidation rates, whether enhanced through previous irradiation or not, were negligible in comparison to radiation induced reactions of a completely different nature. The rates of carbon dioxide evolution during irradiation showed a complex dependence upon the oxygen pressure, flow and the volume of the irradiated gas space upstream of the graphite. The results were interpreted in terms of the radiolysis of oxygen to form ozone, partial reversion of ozone to oxygen and the attack of residual ozone on the graphite. (auth)—NSA. 18337

6.6.4, 8.4.5

Compatibility Problems in the Use of Graphite in Nuclear Reactors. Robert L. Carter. North American Aviation, Inc. Atompraxis, **5,** 142-146 (1959) Apr.-May.

Artificial graphite has long been in use as a thermal reactor moderator medium. Its advantages lie in its low cost, its machineability, its moderate chemical reactivity and its metallurgical stability. It is not exothermically reactive with respect to any common coolant medium except air. Interactions with ordinary structural media begin to be troublesome only as temperatures above 600 C are achieved. It is compatible with a wealth of other moderator media and incidental core materials. (auth).—NSA. 18321

6.6.5, 4.3.3, 3.4.8, 3.2.2

Corrosion of Steel in Concrete. (In German.) Anton Baumel and Hans-

Jurgen Engell. Archiv Eisenhuttenw., **30,** 417-428 (1959) July.

To reproduce processes occurring in reinforced concrete, steel wire was exposed to the action of 0.1 N caustic soda solution or a saturated calcium hydroxide solution with the corrosion resistance by passivation being observed. In the presence of a given amount of Cl-ions destruction of the passivation layer and local corrosion take place. 20 references.—RML. 18259

6.6.6, 3.4.9

Effect of Water on Mechanical Strength of Selected Ceramic Compositions. W. J. Smothers. J. Am. Ceram. Soc., **41,** No. 11, Pt. 1, 440-444 (1958) Nov.

Study of properties of glazes and their effect on strength of certain glaze-body combinations; effects of atmosphere, vacuum, certain gases, glaze, organic liquids as coatings and of coatings with water; strength decreased with moisture in air and with water in coatings; it is suggested great part of strength imparted by so-called compression glaze may be due to moisture protection afforded by it.—BL. 18162

6.6.6, 5.4.2, 6.7.2

Ceramics. John W. Lemmon. Ind. Eng. Chem., **50,** 1433-1437 (1958) Sept.

Protection of metals against oxidation, thermal insulation and electrical insulation at elevated temperatures are among the applications of ceramics. Other developments include information concerning new systems, nuclear fuels, various silicon applications and ceramic-metal combinations. These new developments and a consolidation of older information are included.—NSA. 18190

6.6.7, 5.4.5, 5.4.3

Protective Coatings and Linings in Neoprene. J. G. Blunn. Corrosion Technology, **6,** 67-70 (1959) March.

Survey of neoprene materials used in the protective coatings and lining fields —liquid and sheet neoprene, caulking compounds, putties and adhesives—and some of the practical applications to which they have been put.—BTR. 18216

6.7 Duplex Materials

6.7.2

Thoria Reinforced by Metal Fibers. Y. Baskin, C. A. Arenberg and J. H. Handwerk. Paper before Am. Ceramic Soc., 59th Annual Meeting, Dallas, May 8, 1957. Am. Ceram. Soc. Bull., **38,** No. 7, 345-348 (1959) July.

Thoria compacts containing refractory metal fibers in quantities as low as five percent have considerably better resistance to thermal shock spalling than thoria alone. Of the metals and alloys investigated, molybdenum and niobium gave the best results. Compacts incorporating fibers of these metals have lower elastic moduli and compressive strengths and high thermal conductivity than thoria. Oxidation resistance of molybdenum fiber-reinforced thoria is the best of all combinations investigated, but, owing to the presence of microcracks, it is severely attacked after prolonged exposure to an oxidizing atmosphere at 1000 C. (auth)—NSA. 18241

6.7.2, 3.7.4, 3.2.2

An Investigation of the Mechanical Properties of Cermets as Related to the Microstructure. I. Binder and R. Steinitz. Firth Sterling, Inc. U. S. Wright Air Development Center, U. S. Air Force, Jan., 1959, 95 pp. Available from Office of Technical Services, U. S. Dept. of Commerce, Washington 25, D. C. (Order PB 151722).

This is a report of basic research in correlating changes in the microstructure of cermets with changes in physical properties with a view toward the possibility of eliminating cermet brittleness by changing microstructure. Using 60 titanium carbide-40 nickel as the test material, seven different test groups were formulated, comprising changes in original particle size, processing procedure, and controlled binder addition. Each group was heated in seven different fashions. For each test batch microstructures were correlated with changes in physical properties. Among other conclusions it was indicated that average grain size plays a distinct role in physical properties. Included in the report is a review of cermet literature.—OTS. 18211

6.7.2, 8.8.5, 4.3.2

A Study of CrB Cermet. Riitsu Takagi, Kiyoshi Tamura and Yoshio Tamura. J. Mech. Lab. Japan (Japanese Edition), **11,** No. 4, 140-144 (1957); (English Edition), **3,** No. 2, 96-98 (1957).

Chromic boride powders were made by arc melting under argon, ball-milling and vacuum hot-pressing with or without 10 wt. percent nickel. Optimum hot-pressing temperatures were reduced and the resistance to oxidation, corrosion by nitric acid, hydrochloric acid and sulfuric acid and thermal shock was studied. Electrical resistivity and the modulus of rupture were also determined.—MA. 18005

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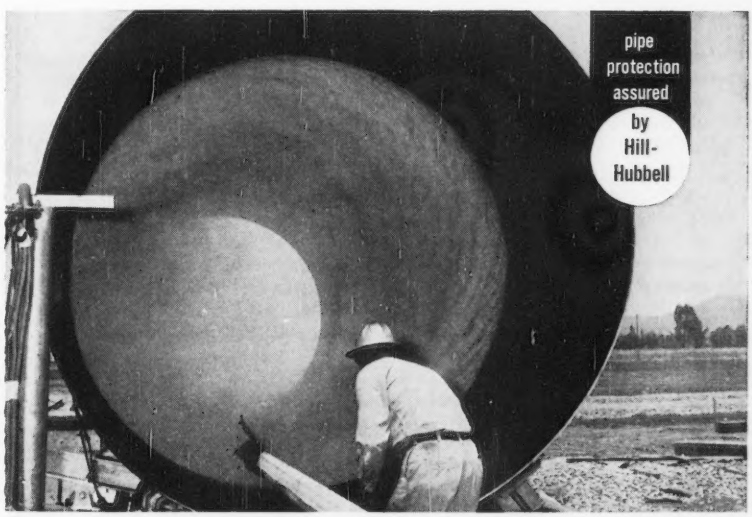

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Current and Potential Relations For the Cathodic Protection of Steel In a High Resistivity Environment*

By W. J. SCHWERDTFEGER*

Abstract

In order to evaluate potential and current criteria for the cathodic protection of bare low-carbon steel in a high-resistivity environment, specimens were exposed in the laboratory for a period of two months to a soil having a resistivity of about 20,000 ohm-centimeter. Previous work in low-resistivity environments has shown that corrosion can be reduced to a negligible degree by polarizing a steel structure to —0.85 volt (protective potential) with reference to a copper-copper sulfate electrode. In such studies, cathodic polarization curves have also been shown to be useful in indicating the current density required for cathodic protection.

In the present study the above criteria were again evaluated. In addition to protecting the steel at the protective potential (free of *IR* drop), the effect on protection of including *IR* drop caused by the protective current was also noted. Also, cathodic polarization curves were obtained on a recorder in conjunction with a bridge circuit to eliminate the *IR* drop.

The results show that the best degree of protection was achieved on the specimen controlled at —0.77 volt (without *IR*) with reference to a saturated calomel half-cell. This is approximately equivalent to the protective potential —0.85 volt with reference to the copper-copper sulfate electrode. Applied current indicated by the break (change-in-slope) in the cathodic polarization curve agreed reasonably well with the actual current necessary to maintain polarization at —0.77 volt (free of *IR*).

The current required for protection was about three times the magnitude of the corrosion current; therefore, the corrosion reaction was either under anodic control (unlike previous studies) or an equivalent type of control which was caused by high resistance at anodic areas. 3.2.4

1. Introduction

STUDIES OF cathodic protection previously carried out in the laboratory at the National Bureau of Standards were all conducted with soils and waters having resistivities less than 1,000 ohm-cm. The experiments showed that the protective potential —0.77 v with reference to the saturated calomel half-cell (equivalent to —0.85 v with reference to the copper-copper sulfate electrode), when free of *IR* drop caused by the protective current, was effective in preventing appreciable loss of metal on steel specimens.[1, 2] Corrosion processes were found to be controlled chiefly by cathodic reactions, and cathodic polarization curves were shown to be very useful in indicating the currents necessary to produce adequate polarization and virtually complete protection.

It was suggested by Sudrabin and Ringer,[3] as a result of some of their recent work, that useful information would be obtained if studies were continued in high-resistivity environments where corrosion rates are controlled largely by electrolytic resistance, rather than by polarization alone. Further research was suggested by the National Association of Corrosion Engineers Unit Committee (T-2C)[4] on "Criteria for Cathodic Protection" under which some task groups have been assigned to: (a) Examine basic criteria that can be used for determining the adequacy of cathodic protection, or (b) Promote research and technical papers on criteria for cathodic protection.

In high-resistivity environments in the field, measured potentials often include considerable *IR* drop as well as polarization voltage resulting from the protective current. As the *IR* drop caused by the applied current within the cathodic branch of a corrosion cell assists in reducing the corrosion cell current, the question arises as to what extent *IR* drop can be tolerated under practical circumstances, for example, in potential measurements made on pipelines.

Cathodic polarization curves are generally recognized as being useful in estimating the current density required for cathodic protection when corrosion reactions are controlled by cathodic polarization (cathodic control). However, there is a question regarding their usefulness when the corrosion current is determined mainly by anodic polarization (anodic control), or when the resistance of the electrolyte (high resistivity) is a limiting factor along with polarization.

The study to be described was conducted by exposing low-carbon steel specimens to a soil (sandy loam) having a resistivity of about 20,000 ohm-cm. In such a high-resistivity environment, it was presumed that the *IR* drop between the reference electrode and the specimen would probably be greater than the polarization voltage and thereby present the opportunity of evaluating the effect of each factor. Preliminary laboratory experiments revealed that cathodic polarization did not take place as readily as in low-resistivity environments and that the currents required for protection were larger than anticipated. This suggested a divergence from the usual cathodic type of control.

2. Experimental Procedure

2.1. General Procedures

All specimens were cut from one piece of cold-drawn steel tubing (1 in. OD by 0.125 inch wall thickness) to lengths of 8 in. The tubes were degreased with carbon tetrachloride and the ends rounded so as to be without burrs. The inner and outer surfaces of the tubes were wire-brushed, smoothed with 1G emery paper, washed in hot water, and then weighed to the nearest milligram. A rubber-covered stranded copper wire was soldered to one end of each specimen for the electrical connection. A coating of oil was made to flow over the inside surface of each tube and both ends plugged with rubber stoppers. A heavy coating of bitumastic was applied over the edges of the tube, covering the wire and soldered connection, insuring a moisture seal around the stopper and leaving 24 in.[2] of cylindrical surface for exposure to the soil.

The soil, a sandy loam from Lanham, Md., after being removed from the field, was air dried and sifted using a No. 10

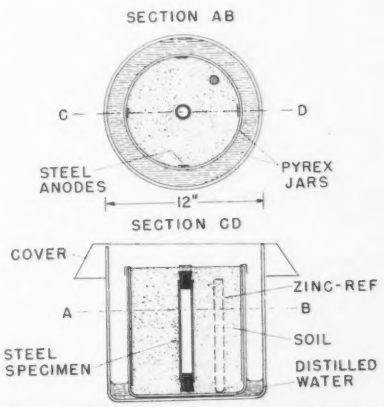

Figure 1—Cross-sectional views of the experimental arrangement for exposing specimens to the soil.

* Reprinted from *J. Research Nat. Bur. of Standards*, 63C, No. 1, 37-45 (1959) July-Sept.

[a] Metallurgy Division, National Bureau of Standards, Washington 25, D. C.

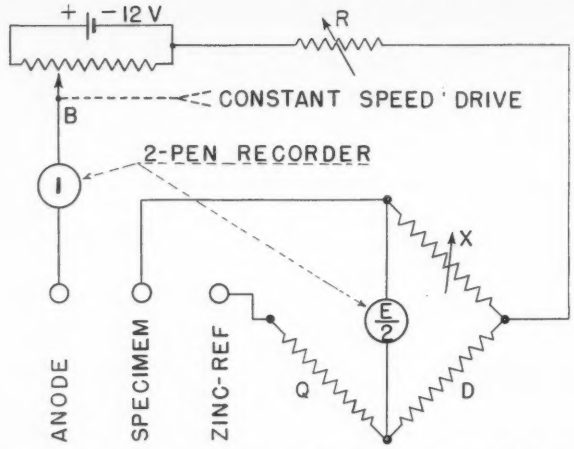

Figure 2—Circuit for obtaining polarization curves automatically and for measuring potentials of specimens free of IR drops. One recorder pen indicated current and the other potential.

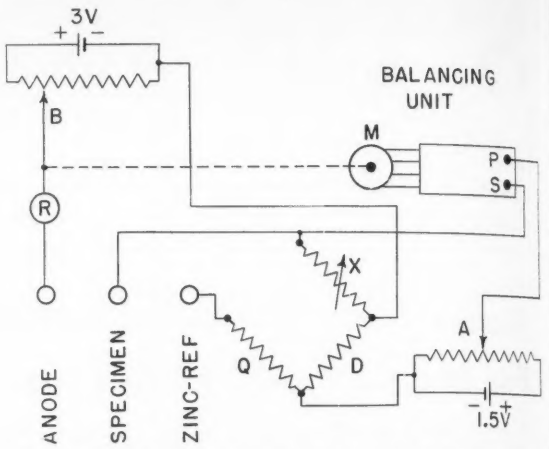

Figure 3—Potential control circuit and bridge circuit for balancing out the IR drop between the specimen and the associated zinc reference electrode. The control voltage, A, was based on the protective potential of the specimen and on the potential of the zinc referred to saturated calomel.

sieve. Preliminary measurements of soil resistivity versus moisture content were made in order to determine a moisture range which provided a fairly stable soil resistivity without saturating the soil. A satisfactory amount of water was found to be about 15 percent by weight of the dry soil. By adding distilled water to the soil this moisture content resulted in a soil resistivity of about 20,000 ohm-cm at 80 F.

Five specimens were used in the experiment, two of which were without cathodic protection, serving as controls, while the other three had currents applied. Exposure to the soil was for a period of 61 days. Four Pyrex jars were used to hold the soil, the two controls being placed in one jar. The soil was moistened in four batches of equal weight, one batch for each jar. The wetting procedure was carried out by slowly adding water to the soil, mixing, adding more water, mixing again, et cetera.

A high-purity zinc rod (0.0375 in. diam by 10 in. long) was permanently exposed to the soil of each jar for use as a reference electrode. Continual or even intermittent ordinary use of an agar-salt bridge to a saturated calomel half-cell would have greatly lowered the soil resistivity. Thus, contact of the soil with an agar-salt bridge was limited to about 10 sec each day in order to measure the potential of the zinc electrode so that the specimen potentials, either measured or controlled, with reference to the zinc could be converted to the saturated calomel scale.

After 61 days of exposure to the soil the specimens were removed for cleaning and measurement of metal loss. The corrosion products, which were very adherent, were loosened by cathodic cleaning for 2 hr at a current density of 1 amp/ft² in a 10-percent solution of ammonium citrate neutralized with ammonium hydroxide. This was followed by scrubbing with a brass bristle brush under hot water. The oil preserved the inner surfaces of the tubes from corrosion. The soldered wire connection was removed by applying heat from a soldering iron and the last bits of solder were removed by scraping with a soft metal tool. Finally all specimens were again rinsed in hot water, blown dry with compressed air, and weighed.

2.2. *Arrangement for Exposure*

Cross-sectional views of the setup for exposure are shown in Figure 1. Two cylindrical Pyrex jars were used, the inner one (8.75 in. OD by 10 in. high) containing the soil, steel specimen and auxiliary electrodes, and an outer jar (12 in. OD by 12 in. high) containing the smaller jar resting in distilled water about 1 in. deep. The outer jar was covered with a loose-fitting inverted pan which helped to control the moisture content of the soil and yet permitted entrance of air. Wires (not shown) from the specimen, zinc reference rod, and steel anodes were brought outside over the edge of the jar slightly tilting the cover as shown. These wires were fastened to the outer wall of the jar.

The specimen and the zinc rod were separated by about 2¾ in. of soil, with ½ in. of soil between the zinc and the jar wall. Four anodes, consisting of strips of sheet steel (1.5 in. wide) running from top to bottom, were interconnected by soldered wires. The surfaces of the anodes adjacent to the glass were covered with insulating tape. Wet soil, prepared as previously described, was packed uniformly around the electrodes. As previously mentioned, the control specimens were both in the same jar. One was centrally located as shown in Figure 1 and the other was in line with the center specimen and the zinc rod and on the side opposite the zinc rod. One inch of soil separated the off-center specimen from the jar wall, the axes of the specimens being parallel to each other.

2.3. *Instrumentation*

Currents were applied to three of the specimens for the entire exposure period. The criterion of cathodic protection for the first specimen was the current adjusted in accordance with values from cathodic polarization curves obtained on the controls. The criterion of protection for the second specimen was the potential —0.77 v (reference saturated calomel electrode) free of IR drop. Protection of the third specimen was also based on the potential —0.77 v, except that the potential included the *IR* drop between the specimen and the reference electrode caused by the externally applied current.

The circuit used for obtaining polarization curves and for measuring potentials free of *IR* drops is shown in Figure 2, the bridge being basically that described by Holler.[5] Resistors Q and D were each 100,000 ohms and the variable resistor, X, was used for balancing out the *IR* drop between the specimen and the reference electrode (zinc). When the bridge was balanced, the actual potential of the specimen was equal to twice the indicated or recorded value. A balanced bridge was indicated by no movement of the recorder pen when the current applied to a specimen was momentarily interrupted. Too small or too large a value of resistance X would cause the pen to suddenly shift in one direction or the other when the applied current was interrupted, but movement of the pen due to changes in polarization emf was relatively minor.

The procedure followed for measuring potentials (without *IR*) of the three specimens under protection was to first measure the current to a specimen and then, without interrupting the current, to transfer the specimen to the voltage supply associated with the bridge circuit, which was preadjusted to furnish the same current. Before reading the potential, the setting of resistor X was checked for bridge balance as described in the previous paragraph or by simply varying resistor X by fixed amounts, above and below the set value, until equal left and right deflections of the potential pen were in evidence.

Cathodic polarization curves were recorded automatically for all specimens on the second and final days of exposure. Both cathodic and anodic polarization curves were recorded on the controls at

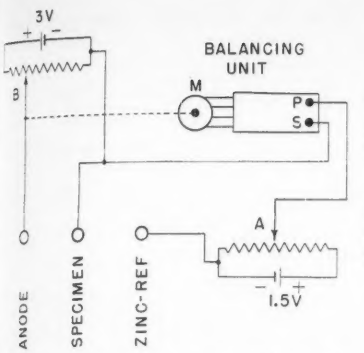

Figure 4—Potential control circuit used on the specimen where the IR drop between it and the zinc reference electrode was included. The control voltage, A, was based on the protective potential of the specimen and on the potential of the associated zinc referred to saturated calomel.

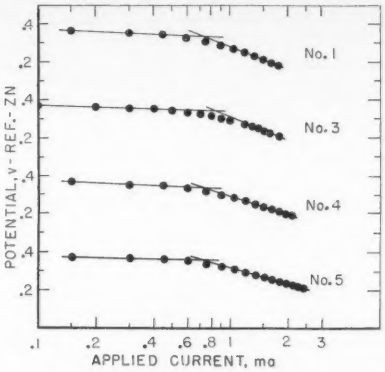

Figure 5—Cathodic polarization data for steel specimens, obtained on the second day of exposure, transferred from recorded charts to semilogarithmic coordinate paper. One milliampere is equivalent to 6 ma/sq ft. After the second day, specimen No. 1 was allowed to corrode freely, except when obtaining polarization data, and protective currents were applied to specimens Nos. 3, 4 and 5.

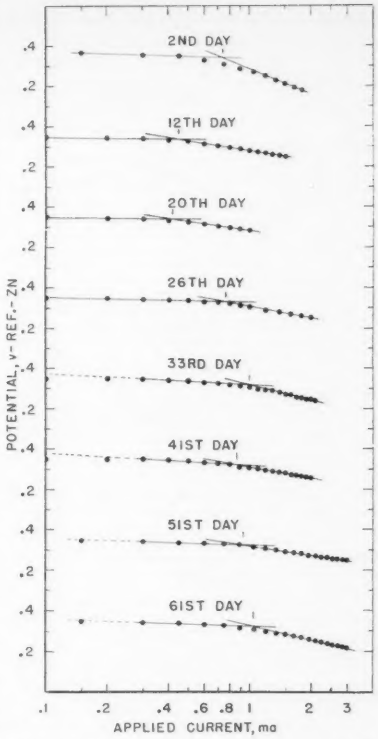

Figure 6—Cathodic polarization curves of control specimen No. 1 at intervals during the exposure period. One milliampere is equivalent to 6 ma/sq ft.

about weekly intervals throughout the exposure period. The polarizing current was varied from zero to a suitable value by linear increments of voltage from a 10-turn voltage divider, shunted across a 12-v storage battery (Figure 2) and driven by a synchronous motor. The rate of polarization could be adjusted by the resistor R, the total polarizing time usually being about 20 minutes.

The specimen under current control was protected with current from a 22.5-v heavy duty dry battery in order that any change in potential of the specimen would make no appreciable change in the current. A series resistance was used for adjusting the current.

The circuit used for controlling the specimen potential at —0.77 (free of *IR*) is shown in Figure 3. It utilizes the bridge circuit just described in conjunction with an electronic balancing unit used previously.[2] The control voltage, A, was adjusted to a value equal to one-half the difference between the potential of the zinc reference electrode and the protective potential for steel. Although the balancing unit was very sensitive to a potential difference across its terminals PS, the accuracy with which the potential of the specimen was actually maintained was obviously also dependent upon two other factors, namely: the stability of the potential of the zinc rod and the actual electrolytic resistance between the specimen and the zinc rod which was presumably balanced out by the variable resistance X. These two factors did change, but the changes were gradual and were not difficult to cope with. Nevertheless, they did limit the accuracy of the potential measurements to perhaps ±20 mv. The applied current was continuously recorded by R (Figure 3).

Figure 4 shows the circuit used for controlling potential at —0.77 v (including *IR*). It is the same as Figure 3, except for the elimination of the bridge circuit. Control voltage A was adjusted to a value equal to the difference in potential between the zinc electrode and the protective potential for steel. Control accuracy here depended chiefly on the stability of the zinc potential and was about ±10 mv.

Currents and potentials were measured daily or less frequently. First, in addition to continuously recording the applied current to the specimen held at —0.77 v (free of *IR*), currents were measured with an indicating milliameter inserted without interrupting the circuits. Next, potentials between the specimens and the zinc electrodes were measured with an indicating potentiometer, *IR* drops caused by applied currents being included. This was followed by measuring the same potentials (without *IR*) by use of the bridge circuit as previously described. Finally, the potentials of the zinc rods were measured with reference to a saturated calomel half-cell. The potentials of the specimens were then converted to the saturated calomel scale and adjustments were made on the control potentiometers, if necessary.

3. Data and Discussion

For the first two days of exposure all specimens were allowed to corrode freely. On the second day, cathodic polarization curves were obtained on one of the controls and on the three specimens subsequently to be placed under cathodic protection. At this time, an anodic polarization curve was also obtained on the same control, with substantially no polarization in evidence. The cathodic curves are shown in Figure 5, plotted on semilogarithmic coordinate paper in order to aid in estimating the change-in-slope point (hereafter designated as I_p) indicated by the intersecting straight lines. Similarly, Figure 6 shows the cathodic polarization curves obtained on control specimen No. 1 at intervals throughout the exposure period. Those for control specimen No. 2 were similar. Hereafter, the currents from these curves and all other measured currents are expressed as current densities in milliameters per square ft.

Currents and potentials measured on the specimens throughout the 61-day exposure period are shown in Figure 7. Figure 8 is similar except that potentials include the *IR* drops, and the potentials of the control specimens are omitted. Specimen No. 3 is the one where current alone was regarded as the protective criterion. The initial current applied to specimen No. 3 was the value shown by the polarization curve (Figure 5), and subsequent adjustments of current were based on the average of currents, I_p, observed on the control specimens Nos. 1 and 2.

From the fourth day onward, specimen No. 4 was controlled at —0.77 v (free of *IR*) and at the same time specimen No. 5 was placed under control at —0.77 v (including *IR*). Currents applied between the 2d and 4th days were estimated to produce the desired effects without control.

In Figures 7 and 8, two values of current or potential for any one specimen on the same day means that adjustments were made. For example, in the case of specimen No. 3, except after the 49th day, the applied current was changed to conform with the polarizing currents, I_p, measured on the controls. However, the resultant changes in potential on that specimen were not measured until the following day or later. When adjusting the potential of specimen No. 4, the control was usually set at —0.78 v, thus allowing a 10-mv margin of safety. In fact, some control difficulties were experienced around the 27th day when for a period of about 7 days the control was even set at a somewhat more negative potential. The changes in applied current resulting from such changes in the potential adjustment were measured the same day as shown in Figures 7 and 8. A mechanical failure in the control equipment caused specimen No. 4 to be without applied current from the 44th to 46th

TABLE 1—Steel Specimens Exposed for Two Months to a High Resistivity (ρ = 20,000 ohm-cm) Soil

Specimen No.	Protective Criterion	Cathodic polarization curve: Current at break, Ip, ma/ft² — Range: Min	Range: Max	Mean	Potential at break E_n[d], V — Range: Min	Range: Max	Mean	Protective Current to specimen, ma/ft² — Range: Min	Range: Max	Mean	Potential of specimen, V: No *IR* — Range: Min	Range: Max	Mean	Including *IR* — Range: Min	Range: Max	Mean	Corrosion[a] current I, ma/ft²	Weight[b] loss of specimen 61 days Mg	Effectiveness of protection,[c] %
1	Control	2.1	6.6	4.6	—0.695	—0.730	—0.710				—0.683	—0.702	—0.689				1.5	375	
2	Control	2.3	8.7	5.0	—.710	—.740	—.721				—.683	—.705	—.689				1.5	375	
3	Current							2.1	9.6	5.2	—.675	—.920	—.777	—0.785	1.12	—0.920		161	57
4	Potential (no *IR*).							[e]1.2	11.4	4.2	[e]—.750	—.820	—.778	[e]—.842	1.10	—.914		107	71
5	Potential (with *IR*)							1.0	4.0	2.1	—.693	—.740	—.717	—.755	—.823	—.780		182	51

[a] Based on Faraday's law, $I = W/kt$, where $K = 2.8938 \times 10^{-4}$ g/coulomb; W = wt loss of controls (average grams); and t = exposure time (seconds).
[b] Corrections made on specimens Nos. 3, 4, and 5 for initial freely corroding period and also for two intermediate days on specimen No. 4 when it was without protective current.
[c] Effectiveness of protection = 100 (*Wc*-*Wp*)/*Wc*, where *Wc* = avg wt loss of controls; and *Wp* = wt loss of the protected specimens.
[d] E_n = open-circuit potential of the anode (average).
[e] Specimen No. 4 was without protective current from the 44th to the 46th day when the potential (min) was actually —0.627v on the 4th day.
NOTE: Each specimen had an exposed area of 24 in.². Potentials are referred to the saturated calomel electrode.
Specimens Nos. 1 and 2 were without cathodic protection.
Specimen No. 3 had current applied based on values of the current, I_p, averaged from polarization curves of specimens Nos. 1 and 2.
Specimen No. 4 was controlled at —0.77 v (no *IR*).
Specimen No. 5 was controlled at —0.77 v (including *IR*).

day. When the trouble was discovered on the 46th day, the potential measured —0.62 v. Before putting the controller back into operation, a cathodic polarization curve was obtained on specimen No. 4 which curve revealed that 4.2 ma/ft² was required for protection. This agreed reasonably well with the values of applied current required for the following 6 days, except for a short time immediately after making adjustments in potential.

After the 22d day of exposure, the polarization on specimen No. 3 began to decrease and the current applied to specimen No. 4 started to increase. It may also be observed (Figure 7) that a few days later, the current to specimen No. 5 began to increase, yet polarization on No. 5 gradually kept falling. On the 26th day, cathodic polarization curves of the controls showed that more current, I_p, was necessary for protection and consequently the current to specimen No. 3 was increased accordingly. Subsequent values of current, I_p, were even larger, yet the potential of specimen No. 3 continued to become less negative until, on the 49th day of exposure, it was decided to arbitrarily increase the current as shown. Even at this high current density (9.5 ma/ft²), maintained for the remainder of exposure, only once did the potential approach —0.77 v.

The foregoing trend of increasing current requirements is not consistent with the results of previous studies[1,2] wherein the current required for cathodic protection usually diminished and leveled off as time of exposure increased. In the previous studies in low-resistivity environments, the corrosion reactions usually closely approached cathodic control. The protective currents ordinarily were equal to or slightly larger (not over 20 percent larger) than the corrosion currents. The results obtained in the present investigation (Table 1) provide an explanation for this divergence. The corrosion current, calculated from the weight losses, is equivalent to a current density of 1.5 ma/ft². A mean-current density of 4.2 ma/ft² was required to protect specimen No. 4 at —0.77 v. This protective current is in fair agreement with the mean currents, I_p, from the cathodic polarization curves of the controls. As the current necessary for protection is about three-times the magnitude of the corrosion current, the corrosion reaction was either under anodic control[6] or a type of control equivalent to anodic control caused by high resistance at the anodic areas. That one condition or the other probably prevailed is supported by the anodic polarization curves (not shown) on the controls which were obtained the same days following cathodic polarization. The anodic curves in the beginning of the exposure period were indicative of cathodic control in that there was very little or no polarization. Later, polarization occurred and the break (change-in-slope) appeared in the anodic curves at currents of about the same magnitude as the cathodic currents, I_p. Finally, during the latter half of the exposure period the anodic curves revealed breaks at currents smaller than I_p. Thus, while the current necessary for cathodic protection increased as the exposure time lengthened, the anodic currents, presumably required to stop local action, became smaller.

The weight losses of specimens Nos. 3, 4, and 5 shown in the table have been adjusted for the time the applied currents were off, namely: 2 days for each of specimens Nos. 3 and 5, and 4 days for specimen No. 4. The adjustments were made on a proportionate basis of the control weight losses. One might conclude that the degree of protection achieved on specimen No. 4 was less than would have been expected, as this specimen was protected at a potential equivalent to —0.85 v free of *IR* with reference to the more familiar Cu-$CuSO_4$ electrode. However, the measured potentials at best were only average values and in the 20,000 ohm-cm soil, because of current distribution difficulties, the potentials on some areas of the exposed surface might not have been at the protective level. Also, the adjustments made in weight losses are actually rather conservative. In the case of specimen No. 4, had the adjustment for the current off periods been based on weight losses calculated from the polarization curves, the degree of protection would have been about 76 percent.

Under the environmental conditions, a comparison of the data pertaining to specimens Nos. 3 and 4 shows the importance of maintaining polarization at the protective potential level if the goal is complete protection. Figure 7 shows that during more than half of the exposure period, the potential of specimen No. 3 was less negative than —0.77 v even though the mean current (Table 1) applied to specimen No. 3 was equal to or greater than that applied to No. 4. Thus, current density alone cannot be relied upon as a satisfactory criterion for cathodic protection.

Assuming that the inherent rates of corrosion on specimens Nos. 3 and 5 were about the same (cathodic polarization curves indicated that they were), it might be concluded that, based on the comparative applied current densities, the corrosion on specimen No. 5 was more economically controlled than that on specimen No. 3. Although more than twice as much current was applied to specimen No. 3, only a slightly better degree of protection resulted. On the other hand, the data also bring out the fact that any benefits of *IR* drop while cathodically protecting a bare surface must be examined with caution. The degree of protection on specimen No. 5 was considerably less than that obtained on specimen No. 4, which received only a fair degree of protection, even though the *IR* drop was not included in the controlled protective potential. Potential values which include *IR* drops can be very misleading, as shown by Figure 8 and the data in the table. In the case of specimen No. 5 (Table 1), based on the mean control potential (—0.689 v), the mean potential change (91 mv), caused by the protective current, to the potential —0.78 v (including *IR*) was comprised of only 28 mv attributable to polarization.

The data pertaining to specimen No. 5 also lead to questions concerning the proper positioning of the reference electrode. It is recognized that, in a theoretical consideration of the potential criterion for cathodic protection, the *IR* drop in the cathodic area of a corrosion cell reduces the cathodic polarization required to fulfill the protective criterion, i.e., polarization to the open-circuit potential of the anode. The benefits of *IR* drop (with reference to current flow to bare surfaces) resulting from applied currents to cathodic

areas have been very ably demonstrated by Miller,[7] Sudrabin,[8] and others. Miller made measurements in a wet clay of about 1,000 ohm-cm resistivity. He showed that the cathode (a rusty iron pipe) of a galvanic cell need not be polarized to the open-circuit potential of the anode (a bright iron pipe) in order to reduce the galvanic current to zero. The additive effect of the *IR* drop within the cathodic branch was made very apparent. Miller showed that the open-circuit anode potential criterion was fulfilled when the reference electrode was placed directly over the anode or when placed in a remote position so as to include all of the cathodic *IR* drop. However, Miller also recognized the possibility that his tests did not necessarily duplicate all actual conditions existing on a pipeline which presumably contains innumerable corrosion cells on its surface. Using a 22,000 ohm-cm resistivity water environment, Sudrabin demonstrated that the open-circuit anode potential (peculiar to the conditions) while the protective current was flowing, was indicative of complete protection if the reference electrode was placed directly over the anode or away from the cathode sufficiently far to include *IR* drop within the boundary of the corrosion cell. He also showed that placing the reference electrode inside of the cell boundary resulted in excessive protective current but positioning it outside of the cell boundary resulted in insufficient protection. Sudrabin found that spacial factors, relative to the anodes and cathodes of a corrosion cell, control the correct location for the reference electrode and that these factors become more significant as the resistivity of the electrolyte is increased.

Measurements made in the laboratory at the National Bureau of Standards have shown that geometric factors should be given consideration when placing the reference electrode for potential measurements while cathodically protecting bare structures.[9]

In the laboratory experiments described in this paper, it appeared as though the corrosion cells on the surface of the steel tubes had small dimensions and consequently any beneficial cathodic *IR* drops must have been close to the metal surface. Were this not so, all the specimens would have received a better degree of protection. If most corrosion underground can be attributed to local action, and there is evidence that it can,[10,11] the inclusion of any *IR* drop must be evaluated with understanding. It might be well to interject the thought brought out by Sudrabin[8] that the location of the reference electrode is not so critical when a highly resistive coating separates the bare metal surface from the corrosive environment.

4. Summary

The external surfaces of low-carbon steel specimens, in the form of tubes, were exposed for a period of 2 months in the laboratory to a soil having a resistivity of about 20,000 ohm-cm.

There were five specimens, two of which were used as freely corroding controls and also for obtaining polarization data at approximately weekly intervals throughout the exposure period while the other three specimens had protective currents applied continuously. Periodically adjusted current was applied to one of the three on the basis of average values of current from the cathodic polarization curves obtained on the controls. Variable current was applied to each of the other two specimens based on the controlled potential —0.77 v referred to the saturated calomel half-cell. The control of the two specimens held at —0.77 v dif-

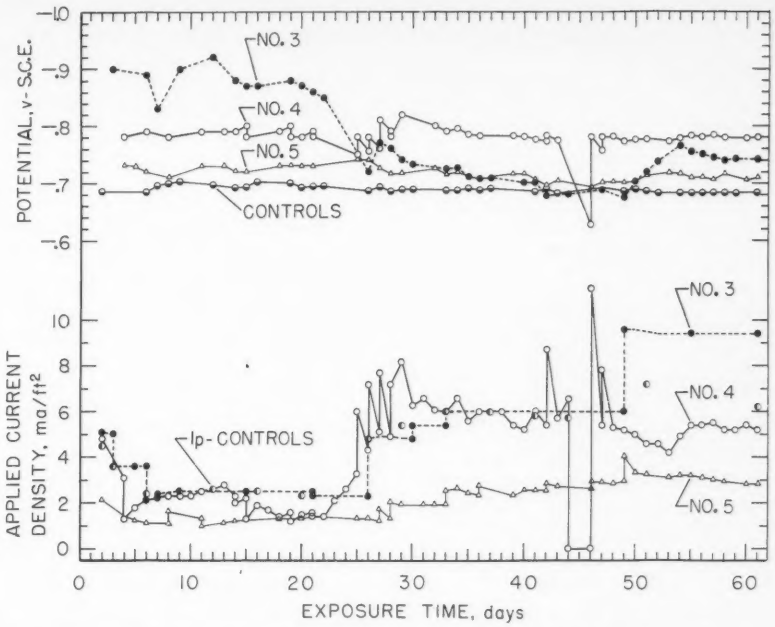

Figure 7—Relationship between potential (no IR) and applied current density for different degrees of cathodic protection on specimens Nos. 3, 4 and 5. SCE means saturated calomel electrode. Ip is the protective current requirement averaged for control specimens Nos. 1 and 2 based on cathodic polarization curves; No. 3 specimen, except after 49th day, constant current conforms with Ip; No. 4 specimen, variable current based on controlled potential —0.77 v (no IR); No. 5 specimen, variable current based on controlled potential —0.77 v (including IR).

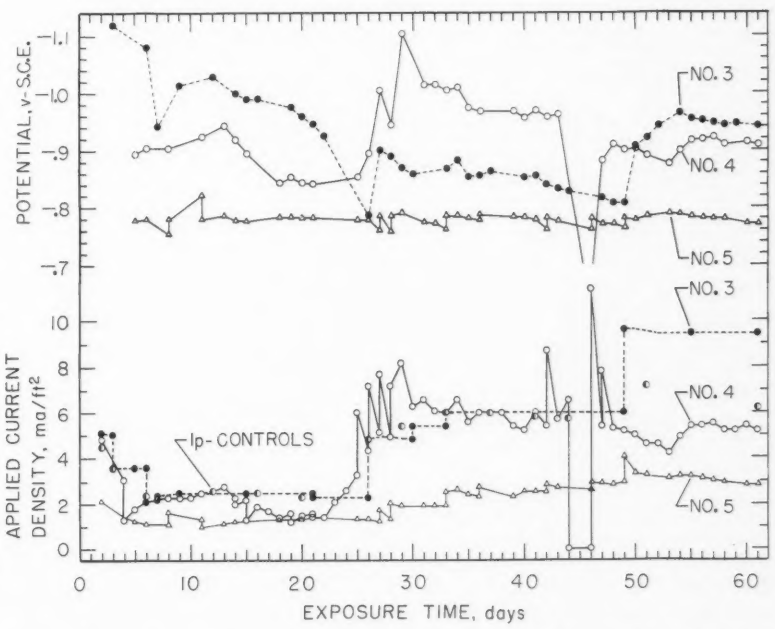

Figure 8—Same as Figure 7, except that all potentials include IR drop, and the potentials of the controls are omitted.

fered in that for one specimen the protective potential included the *IR* drop caused by the protective current between the specimen and a reference electrode (a zinc rod) while the other specimen was controlled without including this *IR* drop.

During the 2-month period of exposure a change occurred from a cathodic type of corrosion control to an anodic type or a type equivalent to anodic, seemingly caused by a high resistance of the anodic areas on the specimens. This was evidenced by the characteristics of the cathodic and the anodic polarization curves of the controls, by increasing currents required for protection at the controlled potentials, and finally by the ratio of the value of protective current to the corrosion current.

The best degree of protection was achieved on the specimen controlled at —0.77 v (free of *IR* drop). The other two specimens were protected to a lesser degree because of insufficient polarization. As in previous laboratory studies at the Bureau, the data show that cathodic polarization curves are a means for measuring the current required for cathodic protection but that the degree of protection being achieved is indicated best by changes in potential resulting from polarization.

The data show that *IR* drop included in a potential reading (indicative of protection) can be very misleading, especially when bare iron or steel is exposed to a high-resistivity environment.

The author thanks E. A. Anderson, New Jersey Zinc Company, for furnishing the high-purity zinc rods used in the experiments.

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Any discussion of this article not published above will appear in the December, 1960 issue.

Electrical Significance of Cathodic Protection On Hazardous Area Steel Docks*

By T. A. MULLETT and J. W. JOHNSTONE, JR.

Introduction

THE ATLANTIC Refining Company and the Atlantic Pipe Line Company have had a measure of success with the installation of impressed current cathodic protection systems at several structural steel docks. These facilities include those in the salt and brackish waters of the Gulf Coast and, more recently, in the tideland waters of the East Coast. Conclusive results in the more recent installations are yet to be determined and in particular there is much to be desired in the successful application of cathodic protection to a steel dock in the fresh water of the Delaware River at Philadelphia.

The application of electrical voltages and currents to dock structures raises a question of safety. At a dock where petroleum cargoes are being handled, the atmosphere may contain flammable mixtures. The simultaneous occurrence of a spark or arc could cause an ignition with disasterous results. Obviously, a clear conception of the hazards which an electrical system such as cathodic protection might present, is desirable.

An investigation was undertaken to determine (1) the critical values of arc and ignition energy which can occur under various conditions of circuit, current and voltage, (2) the actual electrical conditions which exist at cathodically protected steel docks.

The purpose of this paper is to outline the results of this investigation and the conclusions which were reached.

General Design of Steel Dock Cathodic Protection Systems

It has been the general practice of the authors' company to design for an initial impressed current density of 8 ma/ft² of submerged steel dock structure. This current density is reduced to some value below 2 ma/ft² when polarization (—0.85 volt with reference to $Cu\text{-}CuSO_4$ cell) has been attained. The length of time for polarization to occur varies, depending on the nature of the electrolyte and the length of time the system operates continuously. Shut-downs have occurred in the past due to equipment failure and as a precautionary safety measure. There are some indications that steel in fresh water will never polarize unless high current densities are impressed continuously.

The magnitude of total current necessary for 8 ma/ft² current density is about 3200 amperes at one fresh water dock location and is 1200 amperes at a salt water dock location. The voltages necessary to impress these currents vary from 2 volts at one salt water location (polarized) to 20 volts at another salt water location (not yet polarized).

Scrap steel pipe and graphite anodes have been used for the ground beds.

Rectifiers are all out-door, weatherproof, oil-immersed, with selenium stacks, and most are so located as to be in a non-hazardous area. In some instances the rectifiers also meet the requirements of Class I Group D equipment. This occurs where the rectifier is located in a hazardous area or where flexibility is desired so that the rectifier may be used in a hazardous area in the future.

With regard to safety, the systems have been designed and installed to be consistent with the normal safety requirements of any electrical system. In addition, the anode strings have been buried a sufficient distance from the dock (50 ft. minimum) to minimize the possibility of an accidental short circuit due to a falling metallic object, and to prevent shifting of the anode strings due to currents and movement of the bottom.

Operating Practice

An informal survey of the practice of other petroleum companies with cathodically protected steel docks revealed inconsistency. The various cathodic protection system operating practices included, (1) continuous operation at all times, (2) shut-down only while ship approaching the dock, connecting and disconnecting, (3) shut-down for entire period from time when ship approaches dock until ship leaves, and (4) shut-down continuously pending a clearer conception of the safety situation.

Currents and Potentials

It is generally agreed that a potential shift in steel of —0.3 volt is adequate to assure corrosion protection. Now consider the approach of a steel body, such as a ship, which has not had its potential shifted, to a steel dock which has had its potential shifted —0.3 volt (cathodically protected). One expects to find a potential difference of 0.3 volt between the ship and the dock, providing the two are not touching. If one were to connect a conductive path between the ship and the dock, one would expect a current to flow in accordance with Ohm's Law, provided there were enough stored energy in the system.

Both the ship and the dock are in water which will conduct electricity. Consider the ship and the dock as the terminals of a battery, the water path and paint on the hull as internal resistance, and connect and disconnect a conductor from ship to dock. Then:

$$Ic = \frac{Ec}{Rc} = \frac{Eo}{Rc + Ri} \qquad (1)$$

Where:

Ic = current in conductor, amperes
Ec = closed circuit potential, volts
Eo = open circuit potential, volts
Rc = conductor resistance, ohms
Ri = internal resistance, ohms

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Abstract

Test data are reported concerning the electrical situation at cathodically protected steel docks in petroleum service where hazardous atmospheres may exist. Particular attention is paid to the effect of rectifier operation while the ship is in dock. Results and conclusion are reported for investigations of arc energy for the magnitudes encountered at cathodically protected steel docks. Topics discussed include design of steel dock cathodic protection systems, minimum arc energy to cause ignition, and sparking tendencies. Field tests results are reported both for salt water and fresh water docking facilities. Data given include current flow and potential differences from ship to dock, internal and external resistances during salt water docking cathodic protection tests, and rectifier outputs in salt water docking cathodic protection tests. 5.2.1

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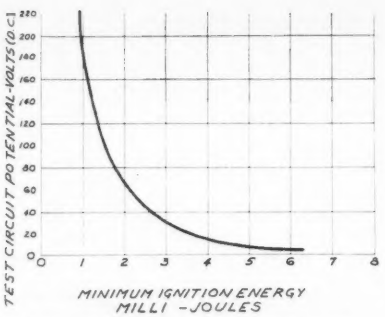

Figure 1—Minimum ignition energy vs circuit potential.

Assume that a considerable amount of energy has been consumed shifting the potential of the dock —0.3 volt. If the internal resistance is high (as it might be in fresh water), the current flow will be low, depending on the value of the conductor resistance, and the voltage will decay slowly (slow discharge rate of the "battery"). On the other hand with a low internal resistance, as might be the case in salt water, and the same conductor as above, the current will be higher and voltage decay faster.

At this point it is indicated that current might easily be controlled by control of the resistance of any conductors which might be connected between ship and dock.

Hazards

Since the currents and potentials mentioned previously are associated with cathodic protection, one considers the hazards that these electrical conditions might create. Obviously pertinent here is the possibility of an electrical arc or spark in the presence of a flammable mixture.

Among the obvious conductors which might purposely or accidentally be connected or disconnected from ship to dock at any time are the bonding cables, metal gangway, steel hawsers and conductive hoses. It will be shown that the bonding cable is of most concern with its inherent low resistance. The circuit continuity of a bonding cable is usually completed in an explosion proof disconnect switch after the free end has been bolted to the ship. Therefore only accidental parting under strain would appear to be potentially hazardous.

Of equal importance is the question of whether or not the energy, associated with making and breaking circuits with the voltages and currents involved in this situation, is great enough to cause an ignition of a flammable mixture.

Ignition Energy

Arcs (sparks) may be divided into capacitance sparks, inductance sparks, fusion sparks and brush discharge (corona). Corona is usually associated with high voltages and ionization of the surrounding atmosphere with glow discharge and the possibility of complete breakdown. Fusion sparks are those developed by the friction contact of two materials. Capacitance sparks are those caused by a capacitive circuit resulting in arcing between fixed separated points. The inductance spark is the type which normally occurs as a result of switching a circuit containing inductance.

It is noted in reviewing literature that the minimum arc energy which will cause ignition is lower for capacitance sparks than for inductance sparks. The reasoning for this is that a capacitance spark is closer to a point source. Hence the energy is more concentrated than the energy of an inductance spark which is spread out over a path. Specifically, it is noted that the minimum energy for ignition of a flammable mixture of certain hydrocarbons is in the order of 0.24 milli-joules, where the electric discharge is complete electric breakdown (capacitance spark discharge) or partial electric breakdown (corona discharge).[1]

A series of tests were conducted by connecting various voltage potential sources in series with known inductances, a variable resistance and a wiping sleeve contact mechanism enclosed in an explosion chamber.[2] Controlled flammable mixtures, predominantly methane-air and coal gas-air, were contained in the explosion chamber at room temperature and atmospheric pressure. The current was varied for each series of tests to determine the minimum current value which would cause ignition of the flammable mixture when contacts in the explosion chamber were opened. Figure 1 is an indication in this instance of the variation in minimum ignition energy for different voltage levels.

The minimum current which will cause an ignition when opening a circuit appears to be closely related to the source voltage and circuit inductance. There are data available which indicate that for very low values of inductance, the igniting current varies from about 0.007 amperes at 800 volts to about 30 amperes at 4 volts.[3] This same reference indicates that in a flammable mixture of grade 115-145 aviation gasoline and air, the minimum ignition current varies from about 0.095 ampere with 1.0 henry of inductance in the circuit (4.5 milli-joules), to approximately 15 amperes with 0.0001 henry of inductance in the circuit (11.2 milli-joules) provided the source potential is 20 volts. If the source potential is 135 volts, the minimum ignition current varies from 0.095 ampere to 0.7 ampere for the same values of circuit inductance.

It appears that there are no reference data available which indicate the magnitude of minimum ignition current (or energy) associated with inductance circuits and source potentials of less than 4.0 volts. However, it seems reasonable to conclude that with source potentials of less than 4.0 volts and inductances of less than 0.001 henry, the minimum ignition energy will be far in excess of the 0.24 milli-joule minimum energy of a capacitance arc and very likely in excess of 6.0 milli-joules.

Arc Energy

The amount of energy in an arc will depend on the capacitance, inductance, and resistance of the circuit, the configuration and speed of separation of the circuit breaking contacts, and the voltage and current in the circuit.

In general it is known that:

$$A_{br} = \int_0^{t_{br}} e_b \cdot i \cdot dt = \frac{1}{v}\int_0^{l_{br}} e \cdot i \cdot dl \qquad (2)$$

where: A_{br} = energy
t = time
e = voltage
i = current
l = length
v = speed

It has been shown that for a pure resistance type circuit, equation (2) may be reduced to the following.[4]

$$A_{br} = \frac{E^2}{CV} \cdot i_o \cdot g(i_o) \qquad (3)$$

where: A_{br} = arc energy in watt-seconds (joules)
E = circuit applied voltage in volt
C = constant (6 volts/cm. in air)
V = velocity in cm/sec.
i_o = initial current before break in circuit, in amperes.

$$g(i_o) = \tfrac{1}{2}\,[f(i_o)]^2 - 1/3\,[f(i_o)]^3$$

$$f(i_o) = 1 - \frac{a}{i_o}\left(\sqrt{1+\frac{i_o}{a}} - 1\right) \Bigg/ \left(1 + \frac{1}{\sqrt{1+\frac{i_o}{a}} - 1}\right)$$

$$a = \frac{d}{C}$$

d = constant (42 W/cm. in air)

If one solves equation (3) for values of $E = 0.3$ volt, $I = 30$ amperes and $V = 6.55$ feet/sec. the resultant arc energy is 0.013 milli-joules, obviously very small.

The equation for energy in an inductance circuit is as follows:

$$W = \tfrac{1}{2}\,L\,I^2 \qquad (4)$$

where: W = Energy in watt-seconds (joules)
L = Inductance in henries
I = Current in amperes

Furthermore the empirical formulae for inductance in coils and straight wire are as follows:

$$\text{Air coil: } L = \frac{0.2\,a^2\,n^2}{3a + 9b + 10c} \qquad (5)$$

where: L = inductance in henries x 10^{-6}
a = average coil diameter in inches
n = number of turns
b = length of winding in inches
c = radial depth of winding in inches

Straight wire:

$$L = (0.002)\;l\;(\ln \frac{2\,l}{r} - \tfrac{3}{4}) \qquad (6)$$

where: L = inductance in henries x 10^{-6}
l = length in cm.
r = radius of conductor in cm.

Consider a No. 4/0 cable, 100 ft. long with 50 ft. coiled (24″ diameter loops) and 50 ft. straight. This might be the actual situation for a bonding cable from ship to dock. Consider the voltage to be 0.4 volt and the current to be 10 amperes. It can be seen that theoretically the total inductance is in the order of 86.5×10^{-6} henries and the resultant arc energy would be about 4.3 millijoules. From the foregoing this would appear to be a safe value, and no ignition should result if the arc occurred in the presence of a flammable mixture.

Purpose of Field Tests

A series of practical tests were undertaken. The tests had the general purpose of defining the electrical situation existing between a tanker and a cathodically protected steel dock during normal loading operations. From such data, it was intended that the hazards, if any, occasioned by dock cathodic protection could be better assessed. More specifically, the tests were designed to determine the items listed immediately below:

1. The electrical potential existing between ship and dock at all stages of docking and loading and with the cathodic protection system both on and off.
2. The individual and total currents flowing in all conductors regularly connected between the ship and dock with the cathodic protection system both on and off.
3. The internal and external resistances in the electrical circuit made up of the ship, dock, water, and conductors.
4. The effect on the output of the dock cathodic protection system when a tanker is berthed at the dock.
5. The level of cathodic protection existing on the dock before and after the docking operations.
6. The tendency of the system to produce sparks or arcs.

Tests were conducted at two locations: Harbor Island, Texas and Fort Mifflin, Pennsylvania. The Harbor Island Dock is in salt water on the Gulf of Mexico near Port Aransas, Texas. The Fort Mifflin dock is in fresh water on the Delaware River near Philadelphia, Pa. The cathodic protection system at the Harbor Island location is considered a model for this type of protection. For all practicable purposes, corrosion of the submerged portions of the steel dock has been arrested. Harbor Island dock, therefore, was selected because it embodied all important conditions which accompany the use of complete cathodic protection in salt water. Fort Mifflin was selected because it embodied the conditions which accompany the use of incomplete cathodic protection in fresh water.

Because many features of the tests were the same at both locations, description of only one investigation is presented in detail—the one conducted at Harbor Island. This is supplemented by a brief description of the important differences in the Fort Mifflin tests.

Harbor Island Field Tests

Dock

The Harbor Island Dock was erected in 1951. Excluding walkways, it is 30′ wide x 260′ long. Except for a concrete deck and timber fender on the face, it is constructed entirely of structural steel. Vertical support members are 12″ and 14″ H-bearing piles. A cross-section of a typical bent is illustrated in Figure 2. In the wetted areas these members are subject to a normal salt water corrosion rate of .003″ to .010″ per year. The wetted area is approximately 100,000 sq. ft.

The dock is equipped with two bonding wire stations. The No. 1 station utilizes 76′ of 2/0 wire cable, and the No. 2 station utilizes 115′ of 4/0. Each of these cables is connected to the dock structure through a switch. These are double pole, single throw, no fuse, quick break, safety switches. They are enclosed in a housing which is suitable for explosion proof, dust tight and weather resistant (rain tight) requirements. Five 8″ cargo hoses were employed during the tests. Two of these were used, first for discharging ballast, and then reconnected for cargo loading.

Cathodic Protection System

The Harbor Island cathodic protection system was energized in January 1954. It was designed for an initial protective current density of 8 ma per sq. ft. of bare, wetted steel surface. This was provided originally by four rectifiers having a DC capacity of 200 amperes at 24 volts.

These were arranged in parallel pairs so that two were connected to a graphite ground bed and two to a scrap steel ground bed. Both ground beds are buried along the shore in the sand bottom of the shallow water behind the dock.

As the result of a build-up of a "calcareous coating" and "residual polarization," the current requirements for maintaining protection have steadily decreased. At the time of test, only one of the original rectifiers operating at a DC output of 174 amps and 3.25 volts was required to give adequate protection as indicated by an average dock potential (to $CuSo_4$) of —.90 volts.

Ship

The Harbor Island tests were conducted during the loading operations of the tanker *Atlantic Seaman*. This vessel has a tonnage of 30,000 DWT. She has an over-all length of 660′ and a beam of 85′. Her wetted surface area varies with draft between 48,000 sq. ft. at 10 ft. draft and 81,500 sq. ft. at 34′-3″ draft. The *Seaman's* last drydocking prior to the tests occurred in January 1958. At that time the hull was given three coats of paint.

Operations

The sequence of operations during which test data were recorded follows:

1. Approach of ship to dock
2. Securing of spring, bow and stern lines
3. Securing of bonding wire
4. Placement of gangway

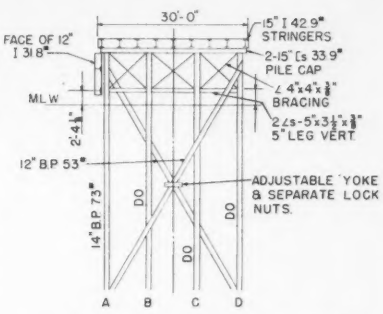

Figure 2—Typical main bent section—steel dock structure.

5. Connection of ballast hoses
6. Pumping and stripping of ballast
7. Connection of cargo hoses
8. Loading of cargo
9. Disconnection of hoses
10. Removal of mooring lines, gangway, and bonding wire

Potential Difference—Ship to Dock

The potential existing between the ship and dock was measured as the ship approached the dock, during loading operations with rectifier on and off, and as the ship left the dock.

Current Flow—In Various Conductors

The current flowing in each of the following conductors was measured at different stages of operation by measuring the voltage drop in calibrated shunts with a milli-voltmeter with the cathodic protection on and off:

1. Bonding Wires 1 and 2
2. Five 8″ Cargo Hoses
3. Gangway

In addition to several readings of current flow in the bonding wires with indicating meters, a continuous record of the current flowing in the No. 1 bonding wire was made using a smoke chart recorder.

Prior to the arrival of the ship, the dock end of the five cargo hoses had been fitted with insulating joints shorted with calibrated shunts to permit measurement of any current flowing through the hoses. Current conducted by the gangway was approximated by placing the dock end on a rubber pad while the other end was in contact with the ship and then measuring the current flowing in a calibrated shunt connected between the dock and the dock end of the gangway through a No. 12 wire. Since steel cables were not used to directly connect this ship to the dock, it was not practicable to obtain a typical measurement of current in mooring cables. However, from other measurements made, it is possible to accurately predict what the maximum value of any such currents might be.

Internal and External Resistances

The internal resistance of this circuit is calculated from the open and closed circuit values for simultaneous measurements of potential and current.

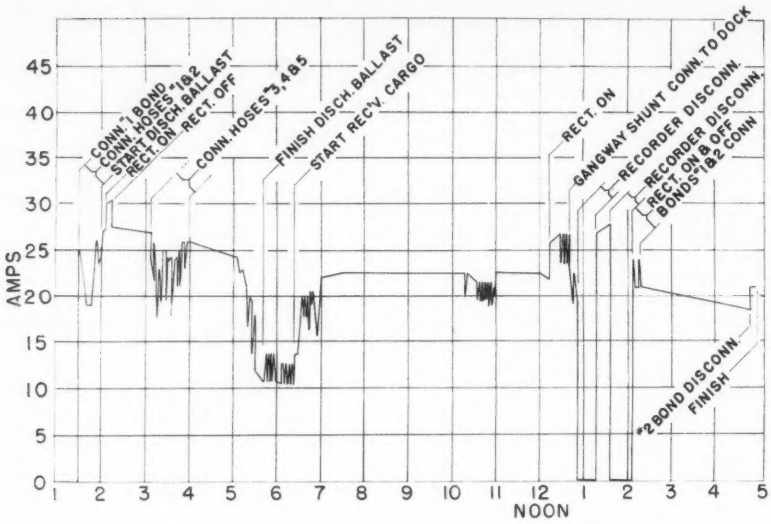

Figure 3—Record of current flow for No. 1 bond wire at Harbor Island dock.

The resistances of the hoses were measured with a Volt-Ohmeter. Prior to the ship arrival, the resistances of the bonding wires were calculated from measurements of current flow and voltage drop occurring through them when connected across two cells of an automobile storage battery.

Rectifier Output

The current and voltage outputs of the cathodic protection system before and after connecting the ship to the dock, and after ship departure, were observed. The current was measured with a millivoltmeter indicating the voltage drop across a calibrated shunt. The voltage was measured with a voltmeter connected across the rectifier output terminals.

Level of Dock Cathodic Protection

The level of dock cathodic protection was determined before and after the test period by measuring the potential of the dock to a copper-sulfate reference electrode. These measurements were made at several locations on the water surface near the dock face with a voltmeter.

Sparking Tendencies

While the ship was connected to the dock with the cathodic protection system both on and off, and with the cover removed from the bonding wire switch, the switch was opened and closed several times at night and the contacts carefully observed for the presence of arcing. At the time of initial lowering of the gangway (which occurred at night) observations were made for the presence of sparks at the moment of gangway contact with the dock.

Fort Mifflin Field Tests

The Fort Mifflin dock contains 62 bents of a design similar to Harbor Island. The wetted area is approximately 415,000 sq. ft. at high tide. It is subject to a corrosion rate of .002" to .0065" per year. The dock is equipped with six bonding stations. Each station consists of approximately 100 ft. of 2/0 or 4/0 insulated wire cable connected to the dock through a disconnect switch. These switches are all weatherproof type construction. Eight inch cargo hoses and an aluminum gangway were used between the ship and the dock at the time of this test and all lines were manila type hawsers.

The cathodic protection system consists of a 500 ampere rectifier, and a steel pipe anode bed installed on the shore side of the dock in the water. The operational plan has been to have the rectifier on only when there are no ships at the dock. Tests from time to time have indicated that, with rectifier on and 0.8 ma/sq. ft. average current density, a portion of the shore side of the dock is cathodically protected, but the river side is not cathodically protected. All evidence indicates that the system has never been operated continuously for a long enough period of time at high enough current densities for a protective coating to have built up on the dock.

The Fort Mifflin tests were conducted during the docking and unloading operations of the tanker *Atlantic Engineer*. This vessel has a tonnage of 30,000 DWT, an over-all length of 650 ft. and a beam of 85 ft. Her wetted surface area when fully loaded to a draft of 34 ft. 3 in. is approximately 80,800 sq. ft. The *Engineer's* last drydocking prior to the test occurred in April 1958, at which time the hull was given three coats of paint.

The major difference in the Fort Mifflin tests was the method used for determining internal resistance. The resistance through the water path between the ship and dock was measured by using a Biddle "Ductor". The "Ductor" is a direct-indicating, cross-coil, low resistance ohmeter which, when properly used, is dependable to within one percent of full scale and has a low range of 0-100 microhms.

The resistance of the bonding circuit between the point of its connection to the dock, through the bonding switch, to the ship lug end of the bonding cable was also measured with the "Ductor" prior to connection. Otherwise the tests at Fort Mifflin were similar to those conducted at Harbor Island.

Field Test Results

Potential Difference—Ship to Dock

At Harbor Island, the potential difference existing between the ship and dock was 0.295 volt maximum as the ship approached the dock. This dropped to 0.240 volts when the ship touched the dock. As additional connections were made and as current was drained to the dock, the potential difference declined. One hour after docking, a value of 0.150 volt was observed with the No. 1 Bond, the gangway and two ballast hoses connected. The continuous record of current flowing in the No. 1 bond wire indicated that a minimum potential difference of approximately 0.075 volt existed for about an hour between the times ballast discharging stopped and cargo loading started. Turning the cathodic protection system on and off changed the potential difference approximately 0.02 volt, the higher value occurring when the rectifier was on.

At Fort Mifflin, the potential difference existing between the ship and dock was 0.030 volt maximum (dock positive) as the ship approached the dock. This value fell to 0.015 volt as the ship touched the dock and to 0.005 volt as the bow lines were being secured. Within five minutes after this low reading, the potential difference rose again to 0.040 volt. Towards the end of the tests, this value had fallen to 0.022 volt. The low values of potential difference are merely indicative that adequate protection had not been obtained at Fort Mifflin. The first time the bonding switch was closed with the rectifier off and the bonding circuit connected between ship and dock, the potential difference fell to between 0.017 and 0.021 volt. This value was down to 0.010 at the end of the test. With the rectifier on and the bonding switch closed, the potential difference varied between 0.0025 volt and 0.007 volt, but was consistently about 0.006 volt.

Current Flow In Various Conductors

At Harbor Island, the potential difference between ship and dock acted to cause current to flow from ship to dock in the wire, hose and gangway paths and from dock to ship in the water path. A continuous record of the current flow in the No. 1 Bond during the Harbor Island tests is depicted in Figure 3.

At Fort Mifflin, the potential difference between ship and dock acted to cause current to flow from dock to ship in the bond wire path. The magnitudes of the currents measured in each case are listed in Table 1.

Internal and External Resistances

The resistances determined at Harbor Island are listed in Table 2.

At Fort Mifflin, the internal resistance of the water path between the ship and the dock, as measured with the "Ductor"

was 0.0430 ohm with the current and potential leads connected normal and 0.0135 ohm with the leads reversed. It is necessary to average out the "Ductor" resistance readings to compensate for the existing potential between the ship and the dock and the current which this potential will push through the "Ductor" circuit. Therefore:

$$\text{Internal Resistance} = \frac{0.0430 + 0.0135}{2} = 0.02825$$

The resistance of the bonding circuit as measured with the "Ductor" was 0.012 ohm. The resistance of the hoses as measured with a megger was 1.25 ohms for one hose and 2.25 ohms for the other hose.

Rectifier Output

The rectifier outputs with and without the ship connected to the dock was determined. These are shown in Table 3.

Level of Dock Cathodic Protection

At Harbor Island, before tests, the average potential to $CuSO_4$ was —.90. Twenty minutes after the tests were completed, the average potential was —.85 with the rectifier either on or off.

At Fort Mifflin, the potential readings between the dock and a copper sulfate reference prior to the arrival of the ship and with the rectifier turned off varied from —0.4 volt at the surface to —0.6 volt at the mud line 4 ft. 0 in. below the surface.

Potential readings between piles of one bent and a copper sulfate reference electrode, with the cathodic protection system rectifier turned on, varied in general from about —0.68 volt to —0.58 volt. The lower readings were noted on the piles farthest from the shore.

Sparking Tendencies

Close observation when the bond switch contacts were repeatedly opened and closed revealed no arcing. No sparks or arcs were observed when the gangway contacted the dock.

Conclusions

1. In general, the tests substantiated the existence of the conditions which one could expect to accompany application of cathodic protection to steel docks. Cathodic protection of steel docks results in potential differences between the vessel and the dock which cause an increase in current flow through bonding cables and other conductive paths.

2. The maximum potential difference measured between the ship and dock at Harbor Island was 0.295 volt and at Fort Mifflin was 0.040 volt. The polarity of a protected dock must be negative, so current flows from the surrounding water or from a ship to the dock. Tests at Harbor Island showed that surface polarization of the dock structure maintained this difference, subject to a gradual decline, for a considerable period of time after the rectifier had been turned off.

3. The maximum total current flow measured at Harbor Island was 57 amperes and at Fort Mifflin was 1.08 amperes.

4. The total resistance of the Harbor Island system with the No. 1 bonding cable was approximately 0.009 ohm, of which the No. 1 bonding cable accounted for 0.008 ohm and of which the internal resistance was checked by a separate test to be 0.001 ohm. Corresponding results at Fort Mifflin showed a higher total resistance of 0.040 ohm. This includes a bond resistance of 0.012 ohm and an internal resistance (fresh water) of 0.028 ohm.

5. It can be shown that the magnitude of the current flowing in any connecting conductor will depend on the potential difference, the resistance of the conduc-

TABLE 1—Current Flow and Potential Difference, Ship to Dock

Item	Harbor Island Dock Connection To Vessel	RECTIFIER OFF: Potential Difference, Ship To Dock	RECTIFIER OFF: Current Flow, Amperes, Ship To Dock	RECTIFIER OFF: Total External Resistance, Ohms	RECTIFIER ON: Potential Difference, Ship To Dock	RECTIFIER ON: Current Flow, Amperes, Ship To Dock	RECTIFIER ON: Total Resistance, Ohms
1	Vessel 10′ from dock, no connection	0.280 v.	....	.....	.....	.....	.....
2	Vessel at dock, no connection	0.210 v.	0	.....	0.235 v.	0	.....
3	No. 1 bond cable alone	0.190 v.	20.4	.00931	0.215 v.	23.0	.00935
4	No. 2 bond cable alone	0.195 v.	31.6	.00617	0.210 v.	34.0	.00618
5	No. 1 & No. 2 bond cables, no other connections	0.170 v.	47.5	.00358	0.190 v.	52.8	.00360
6	Current in gangway only with No. 1 bond cable & 5 hoses connected	0.165 v.	3.15*	.052	.....	3.6	.....
7	No. 1 Hose**	.....	0	.....	.....	0	.....
8	No. 2 Hose**	.....	.32–.37	.....	.....	.37–45	.....
9	No. 3 Hose**	.....	.25	.....	.....	.56–.58	.....
10	No. 4 Hose**	.....	0	.....	.....	0	.....
11	No. 5 Hose**	.....	0	.....	.....	0	.....
12	Calculated maximum total current with both bonds, gangway & 5 Hoses connected (sum of Items 5-11)	0.170 v.	51.27	.00332	0.190 v.	57.43	.00331
	Fort Mifflin Dock	**Dock To Ship**	**Dock To Ship**		**Dock To Ship**	**Dock To Ship**	
13	No. 1 bond cable alone within 1st hour	13. mv.	1.082	.0120	7. mv.	0.582	.0120
14	After 4 to 6 hours	10. mv.	0.84	.0119	6. mv.	0.50	.0120

* .05 amp. change between gangway contacting and not contacting dock.
** Current in individual hoses with gangway, No. 1 bond cable and 5 hoses connected.

TABLE 2—Resistances (Harbor Island Dock Cathodic Protection Tests)

QUANTITY	INTERNAL RESISTANCE: Rectifier Off	INTERNAL RESISTANCE: Rectifier On
E_o—Ship to dock potential—No bond	.210 Volts	.235 Volts
E_1—Ship to dock potential—No. 1 bond connected	.190 Volts	.215 Volts
$\triangle E$ E_o-E_1	.02 Volts	.02 Volts
I_1 Current Flow—No. 1 Bond	20.4 Amps	23.0 Amps
R_1 Internal Resistance— $\frac{\triangle E}{I_1}$	.000984 Ohms	.00087 Ohms

ITEM	EXTERNAL RESISTANCES (OHMS): Disconnected From Ship	EXTERNAL RESISTANCES (OHMS): When Connected To Ship
No. 1 Bond Wire	.00803	.00803
No. 2 Bond Wire	.0062	.0062
No. 1 Hose (Sections No. 1 & 14)	15,000	Infinite
No. 2 Hose (Sections No. 179 & 180)	.80	.44
No. 3 Hose (Sections No. 3 & 13)	.75	.35
No. 4 Hose (Sections No. 5 & 15)	1,100,000	Infinite
No. 5 Hose (Sections No. 9, 16, & 10)	.05	Infinite

TABLE 3—Rectifier Outputs

Test Location	When Readings Made	Volts	Amperes
Harbor Island Dock	1. Before ship arrival	3.25	174
Harbor Island Dock	2. With No. 1 bond, gangway, and cargo flowing in 5 hoses after rectifier had been off 2½ hours	3.9	186
Harbor Island Dock	3. With conditions same as above except rectifier had been off 14½ hours	3.1	161
Harbor Island Dock	4. After ship departure	3.5	190

Test Location	Readings Made In Sequence	Volts	Amperes
Ft. Mifflin	1. First time rectifier was turned on during tests with bond switch closed	22	350
Ft. Mifflin	2. Thirty seconds later—bond switch open	22	350
Ft. Mifflin	3. One hour and a half later—bond switch closed	22	335
Ft. Mifflin	4. Thirty seconds later—bond switch open	22	335
Ft. Mifflin	5. Three minutes later—bond switch closed	22	330

tor, the internal resistance of the circuit and the relative magnitudes of these two resistances. From the data obtained from the tests, and from the literature on arc energy it was found that the voltage and current between the steel ships and cathodically protected docks can be controlled at a safe level by proper selection of bond resistance.

6. The change in current output on the cathodic protection system while the protection system is turned on, brought about by the connection of a steel ship to a protected dock, was so slight as to be of no practical consequence. This is accounted for by the fact that the current output of a rectifier is determined primarily by the design of the anode and in a secondary manner by the arrangement of the surface of the protected structure in relationship to the anode. When a ship is located near the structure, but is remote from the anode, it will have a relatively small effect in the total current.

7. The level of dock protection was influenced by the presence of the steel ship whether the ship was connected to the dock or not. The level of protection, especially on the dock face, was temporarily lowered. This effect is the natural tendency of two different potentials of two objects to equalize after a period of time to some intermediate value. Fortunately, at Harbor Island the temporary decline in the level of protection occurs mainly on the face of the dock adjacent to the ship. After the ship sails, protective conditions are soon restored.

8. Careful observations of bond switch contacts while being opened and closed revealed no sparks or arcs.

Acknowledgment

The authors wish to thank The Atlantic Refining Company and the Atlantic Pipe Line Company for permission to publish this information. In addition, the authors wish to express their appreciation for the valuable cooperation and assistance of other individuals from The Atlantic Refining Company, including H. A. Diek and J. H. Myers; and from the Atlantic Pipe Line Company, including R. M. Keller and T. Williamson.

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1. A. Klinkenberg and J. L. van der Minne. Electrostatics in the Petroleum Industry. Elsevier Publishing Company, Amsterdam, 1958.
2. J. D. Morgan. The Principles of Ignition. Sir Isaac Pitman and Sons, London, 1942.
3. Lee E. Cuckler. Intrinsic Safety in Instrument and Electrical Circuits. Paper presented May 1957, 22nd Midyear Meeting of The American Petroleum Institute.
4. Emil Alm. Physical Properties of Arcs in Circuit Breakers. Published in Transactions of the Royal Institute of Technology, Stockholm, Sweden, 1949.

DISCUSSION

Question by Sidney Tudor, New York Naval Shipyard, Brooklyn, N. Y.:

Do you consider that the two systems you described, when operated within the 0.4 volt maximum potential changes you specified, are safe under all conditions of bonding, switching or isolation?

Reply by Thomas A. Mullett and J. W. Johnstone, Jr.:

We consider the systems described as safe when operated within the 0.4 volt maximum potential change, provided:

1. Each bonding switch is in a suitable Class I, Group D, explosion-proof housing.

2. Bonding connections are made before the bonding switch is closed and broken after the bonding switch is open.

3. Each bonding cable is not longer than 100 feet.

4. Each bonding cable circuit has a controlled resistance which will limit current to 10 amperes or less with 0.4 volt impressed.

Question by B. J. Philibert, Baltimore, Maryland:

Was a protective coating used on the piling?

Reply by Thomas A. Mullett and J. W. Johnstone, Jr.:

The constantly wetted areas of the steel docks discussed in this paper do not have a protective coating. Based on small scale tests conducted at Fort Mifflin, we would expect a coal tar coating applied to the piles before driving to make a substantial reduction in the current requirement for cathodic protection.

A portion of the tidal zone, the splash zone and the atmospheric zone all have protective coatings. At Harbor Island, the tidal and splash areas are protected with 2″ thick wire-reinforced gunite and the atmospheric zone with a spray-applied coating (30 sq. ft./gal.) of a proprietary grease-type rust preventive. At Fort Mifflin, one material was used for the tidal, splash and atmospheric zones. It is commercially available coal tar emulsion.

Steel docks at two other locations, Newark, New Jersey and New Haven, Connecticut, which include cathodic protection installations, also have no coating on the constantly wetted areas. The upper half of the tidal zone and the splash zone are protected with a three coat system of coal tar consisting of a primer, hot applied pipe line enamel and coal tar emulsion. The atmospheric portions at these locations are protected with the primer and emulsion only. A test rack of five different coatings is installed at the Newark location to gain additional experience with other materials.

Any discussion of this article not published above will appear in the December, 1960 issue.

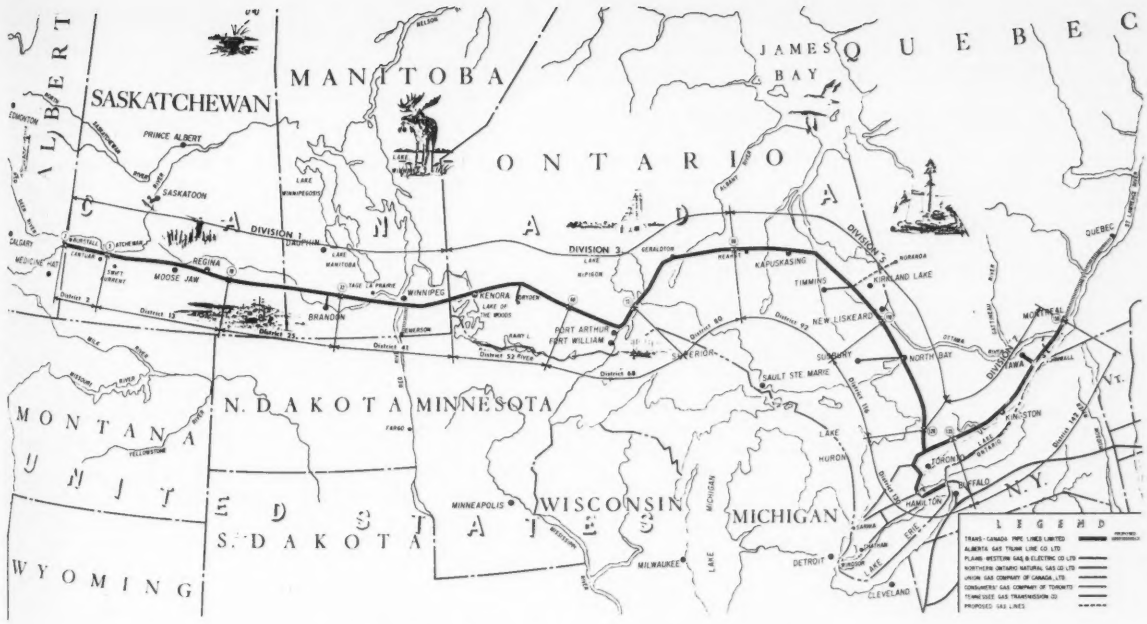


Figure 1—Breakdown of pipe line system into divisions and districts.

Organization and Operation Of Corrosion Field Forces*

By LANCE F. HEVERLY

Abstract

The duties and work functions of corrosion control personnel in a natural gas pipe line company are outlined. Topics discussed include organizational set-up of the company's Corrosion Section, handling and processing of work order requests, duties of the corrosion supervisor, duties of the division corrosion technician, and education and training of district corrosion personnel. Considerable data are given on company recommended cathodic protection installation procedures. 1.7.3

Introduction

THE TRANS-CANADA Pipe Lines Limited system consists of a natural gas pipe line which runs from the Alberta-Saskatchewan border across three provinces to Montreal, a distance of 2,290 miles. It is comprised of three main sections: from the Alberta-Saskatchewan border to Winnipeg, 585 miles of 34-inch pipe; from Winnipeg to Toronto, 1,246 miles of 30-inch pipe; from Toronto to Montreal, 310 miles of 20-inch pipe. In this last main section there are also 33 miles of 24-inch pipe connecting the main system with the 76-mile Toronto-Niagara line and 36 miles of 12-inch pipe connecting the Montreal extension to Ottawa from Morrisburg, Ontario.

The line traverses prairie and sand-hill country, rock, muskeg, swamp, river, stream and lake. About 15 to 20 percent of the route across Northern Ontario was through heavy granite rock, particularly in the western section of the province. About 15 percent of the distance between the Manitoba-Ontario border and Port Arthur was through water and muskeg. In all, rock excavation amounted to a total of 530 miles, swampy ground for 139 miles, 99 river crossings, 85 stream, creek and canal crossings, 202 highway crossings and 96 railway crossings. The longest river crossing was ½ mile wide near Kenora, Ontario and the longest water crossing was 1.2 miles of heavy wall pipe across the Lake of Two Mountains in the approach to the Island of Montreal.

Some other interesting statistics relevant to the building of this line include: tons of steel in pipe—655,640; carloads of pipe, other materials and equipment—43,000; cubic yards of excavation—8,930; contractor employees at construction peak—5,000; miles of pipe wrapping—13,700 outerwrap and 13,700 glass fibre—all at a total of $375,000,000.00.

The Management at Trans-Canada, recognizes the value of a corrosion control program. The experience of older companies whose studies revealed a 30 percent annual return on investment in cathodic protection equipment made this type of investment well worthwhile. One of the never-ending jobs, however, was that of selling cathodic protection all the way down the rank and file.

All corrosion tests, designs, specifications and installation work were carried on under the supervision of the Corrosion Section, a part of the Operations Department. To best outline how this section functions is to describe the organizational set-up.

About the Author

L. F. HEVERLY is Corrosion Supervisor for Trans-Canada Pipe Lines Limited, Toronto, Ontario. He holds a BS in electrical engineering from Pennsylvania State College (1938), and is a member of Tau Beta Pi, Eta Kappa Nu, Pi Mu Epsilon, Sigma Tau and Phi Eta Sigma. He is a Registered Professional Engineer, State of Pennsylvania and Province of Ontario. Mr. Heverly started corrosion work in 1941 for Long Lines Plant Department of American Telephone and Telegraph Company. He was a Corrosion Engineer for Ebasco Services, Incorporated for three and one-half years and Chief Corrosion Engineer for Great Lakes Pipe Line Company for over four years. He was first chairman of Kansas City local chapter of NACE, and is now serving as chairman of Technical Practice Committee T-2D, Procedures for Measuring Pipe Coating Conductance.

*Submitted for publication October 19, 1959. A paper presented at a meeting of the South Central Region, National Association of Corrosion Engineers, Denver, Colorado, October 12-15, 1959.

101 Header Cable consisting of AWG #4 19-Strand, Soft Annealed, Anaconda Type CP Cable (high grade Polyethylene insulation and red Densheath jacket) buried in 2½ to 3 ft. deep trench that is free of all rocks.

102 12-in. Augured Hole x 11 ft. deep. 15 holes required per ground bed.

103 Coal Coke Breeze (approx. four 85-lb. bags per hole), continuous tamping required. Effective length of anode is 8 ft. All foreign matter must be excluded from coke breeze.

104 3-in. dia. x 60-in. lg. Nat'l Carbon Co. Graphite Anode with Pigtail consisting of #8 Stranded Oil-Resistant and Waterproof Cable. Anode to be carefully centered in hole holding graphite top portion of anode with hand - do not support anode by #8 cable.

105 Plico Anode Cap Kit, #AC-3, cemented to top of anode per manufacturer's instructions.

106 Burndy YC4C8 Crimpit Connector for joining #8 stranded to #4 stranded copper cable. Crimp connector in place with 3 crimps and then use a small piece of 1¼-in. wide by ½-in. long "Scotchfil" on each side of Burndy connector to fill in difference in thickness of Burndy connector and #4 Cable on the one side and #4 and #8 cables on the other side. Thoroughly tape with four half-lapped layers of 3/4-in. wide U.S. Korona Splicing Compound making sure to overlap existing insulation on both #4 and #8 cables. Then thoroughly tape with four half-lapped layers of 3/4-in wide 3M "Scotch" #33 Electrical Tape in same manner. Connection must be absolutely moistureproof. See Detail "A".

107 Burndy YS4C-LN4D for butt connecting #4 stranded copper cable when necessary. Use 2 crimps for each cable end. Insulate as specified in Item 106. Connection must be absolutely moistureproof. For square cable cutting, first tape insulated cable with 3M tape and then cut through taped portion with hack saw.

111 #15 Cadweld Charges with Copper Sleeves and Discs (for connecting #4 19-strand cable to pipe by grouping strands into 5-threes and 1-four).

112 Mummy Wax for covering exposed pipe and connections in Item 111.

113 Type D, 2-in. dia. x 60-in. lg. Duriron Anode (with 5-ft. of No. 8, 7-strand high-density Polyethylene insulated cable attached at one end).

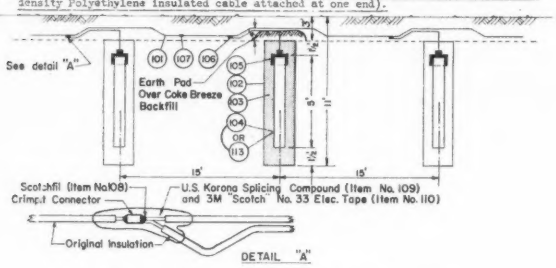


Figure 2—Typical vertical ground bed installation.

101 Header Cable consisting of AWG #4 19-Strand, Soft Annealed, Anaconda Type CP Cable (high grade polyethylene insulation and red Densheath jacket) buried in 3 to 7 ft. deep trench that is free of all rocks. Header cable to be strung out in bottom corner of trench as shown after coke breeze has been tamped and covered with soil.

102 3-ft. wide x 3-ft. to 7-ft. deep trench x 225-ft. long.

103 Coal Coke Breeze (125 to 130 85-lb. bags) in 1 ft. x 1 ft. trench as shown. Continuous tamping required. All foreign matter must be excluded from coke breeze.

104 3-in. dia. x 60-in. lg. Nat'l. Carbon Co. Graphite Anode with Pigtail consisting of #8 Stranded Oil-Resistant and Waterproof Cable. Anode to be carefully centered in trench on 15-ft. centers. 15 required per ground bed.

105 Plico Anode Cap Kit, #AC-3, cemented to end of anode per manufacturer's instructions.

106 Burndy YC4C8 Crimpit Connector for joining #8 Stranded to #4 Stranded Copper Cable. Crimp connector in place with 3 crimps and then use a small piece of 1¼-in. wide by ½-in. long "Scotchfil" on each side of Burndy connector to fill in difference in thickness of Burndy connector and #4 Cable on the one side and #4 and #8 cables on the other side. Thoroughly tape with four half-lapped layers of 3/4-in. wide U.S. Korona Splicing Compound making sure to overlap existing insulation on both #4 and #8 cables. Then thoroughly tape with four half-lapped layers of 3/4-in. wide 3M "Scotch" #33 Electrical Tape in same manner. Connection must be absolutely moisture-proof. See Detail "A".

107 Burndy YS4C-LN4D for butt connecting #4 stranded copper cable when necessary. Use 2 crimps for each cable end. Insulate as specified in Item 106. Connection must be absolutely moistureproof. For square cable cutting, first tape insulated cable with 3M tape and cut through taped portion with hack saw.

111 #15 Cadweld Charge with Copper Sleeve and Disc (for connecting #4 19-Strand cable to pipe by grouping strands into 5-three's and 1-four).

112 Mummy Wax for covering exposed pipe and connections in Item 111.

113 Type D, 2-in. dia. x 60-in. lg. Duriron Anode (with 5-ft. of No. 8, 7-strand high-density Polyethylene insulated cable attached at one end).

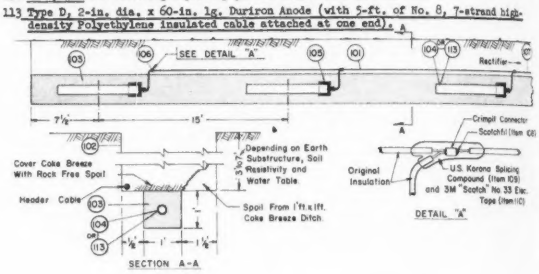
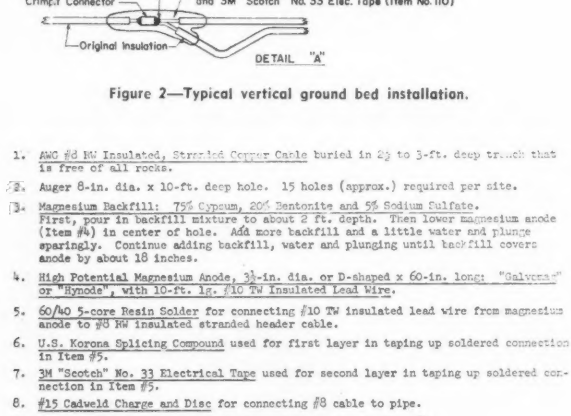


Figure 3—Typical horizontal ground bed installation.

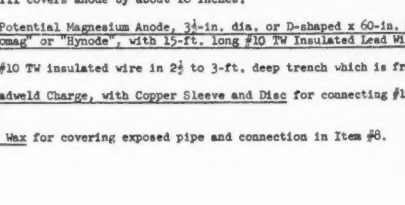
1. AWG #4 HW Insulated, Stranded Copper Cable buried in 2½ to 3-ft. deep trench that is free of all rocks.
2. Auger 8-in. dia. x 10-ft. deep hole. 15 holes (approx.) required per site.
3. Magnesium Backfill: 75% Gypsum, 20% Bentonite and 5% Sodium Sulfate. First, pour in backfill mixture to about 2 ft. depth. Then lower magnesium anode (Item #4) in center of hole. Add more backfill and a little water and plunge sparingly. Continue adding backfill, water and plunging until backfill covers anode by about 18 inches.
4. High Potential Magnesium Anode, 3½-in. dia. or D-shaped x 60-in. long: "Galvomag" or "Hynode", with 10-ft. lg. #10 TW Insulated Lead Wire.
5. 60/40 5-core Resin Solder for connecting #10 TW insulated lead wire from magnesium anode to #8 HW insulated stranded header cable.
6. U.S. Korona Splicing Compound used for first layer in taping up soldered connection in Item #5.
7. 3M "Scotch" No. 33 Electrical Tape used for second layer in taping up soldered connection in Item #5.
8. #15 Cadweld Charge and Disc for connecting #8 cable to pipe.
9. Mummy Wax for covering exposed pipe and connection in Item #8.
10. 4-in. x 4-in. x 6-ft. lg. Pressure Treated Creosoted Post.
11. 1-in. GRP Conduit complete with MCM-7 Terminal Block, Cover & Gasket.
12. 1-in. x 5-ft. lg. Hot-dipped Galvanized Conduit with one end threaded.
13. 6-in. lg. Rubber Hose (O.D. to fit Conduit I.D.) inserted halfway into end of conduit after reaming out burrs.
14. 2-Hole (1/8-in. dia.) Conduit Strap for 1-in. Conduit, Hot-dipped Galvanized.



Space Mg Anodes not less than 10' apart except where limited by space requirements or where it is desired to reduce current output per anode as in the case of low resistance soils.

Figure 4—Typical vertical magnesium installation.

2. Auger 8-in. dia. x 10-ft. deep hole.
3. Magnesium Backfill: 75% Gypsum, 20% Bentonite and 5% Sodium Sulfate. First, pour in backfill mixture to about 2-ft. depth. Then lower magnesium anode (Item #4) in centre of hole. Add more backfill and a little water and plunge sparingly. Continue adding backfill, water and plunging until backfill covers anode by about 18 inches.
4. High Potential Magnesium Anode, 3½-in. dia. or D-shaped x 60-in. long: "Galvomag" or "Hynode", with 15-ft. long #10 TW Insulated Lead Wire.
5. Bury #10 TW insulated wire in 2½ to 3-ft. deep trench which is free of rocks.
8. #15 Cadweld Charge, with Copper Sleeve and Disc for connecting #10 wire to pipe.
9. Mummy Wax for covering exposed pipe and connection in Item #8.



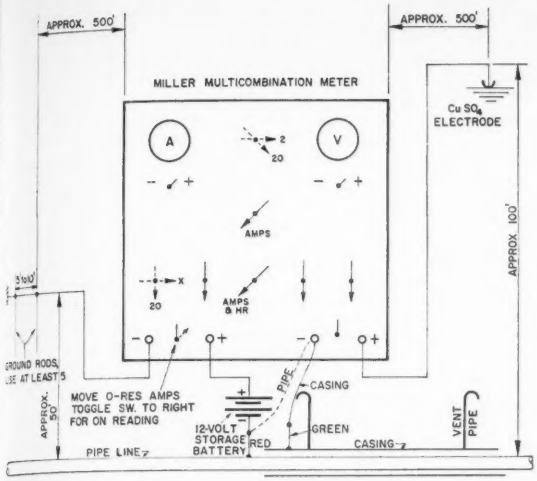
Anode to be 10' from pipe line, number and spacing between anodes determined by the design specifications.

Figure 5—Typical vertical single magnesium anode installation.

Operating Department

The Operating Department is set up on an integrated basis, that is, all instructions and work functions originating from company headquarters office in Toronto are funneled through division superintendents to the field. Conversely, all questions originating in the field are handled either at the field level by district superintendents or through them by division superintendents. If division superintendents and their staff require additional advice, such inquiries are forwarded through them to the Toronto headquarters office. Thus division superintendents are delegated the responsibility and authority for handling the performance of all work functions within their respective divisional areas.

Figure 1 shows the present breakdown of the pipe line system into four divisions and eleven districts.

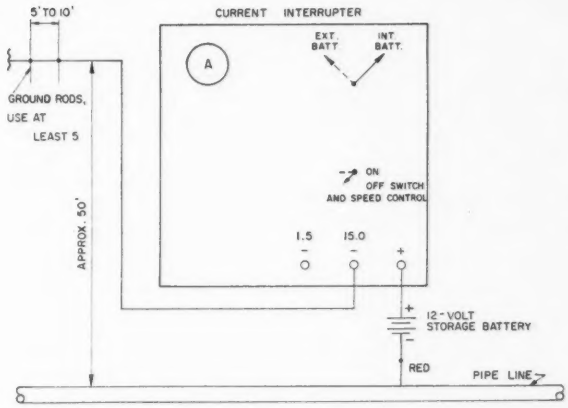


ABOVE SET UP FOR OBTAINING:

(1) CHANGE IN VOLTAGE OF CASING-TO-SOIL WHILE ENERGIZING AND DE-ENERGIZING PIPE THROUGH AMMETER AND STORAGE BATTERY BY MOVING AMMETER TOGGLE SWITCH ON MULTICOMBINATION METER TO THE RIGHT AND BACK TO VERTICAL POSITION. IF NO CHANGE IN CASING-TO-SOIL VOLTAGE, IT WILL NOT BE NECESSARY TO CONTINUE WITH STEPS 2 TO 5

(2) CHANGE IN VOLTAGE OF PIPE-TO-SOIL: SAME AS ABOVE EXCEPT CONNECTION IS MADE TO PIPE AS SHOWN IN ABOVE DIAGRAM BY DOTTED LINE FROM RED LEAD WIRE. THIS CONNECTION IS USED TO OBSERVE PIPE POTENTIAL CHANGE WHEN CLOSING TOGGLE SWITCH.

Figure 6—Check for casing short by comparison method (Step 1).



LOCATE THIS POINT PREFERABLY NOT CLOSER THAN 1000FT. FROM CASING TO BE CHECKED

Figure 7—Interrupter set-up for energizing and de-energizing pipe line to check for casing short by resistance measurement.

Corrosion Section

The Corrosion Section of the Operating Department is designed to fit in with this integrated organizational set-up. To enhance a better understanding and interest in the general problem of corrosion by operating personnel, installation and maintenance of all cathodic protection systems is handled by operating people through division superintendents. In this manner it is expected that company personnel from top management right down to the field laborer will better appreciate the economies of corrosion preventive measures. These economies include the reduction or elimination of: (1) repair or partial replacement of pipe lines due to the effect of corrosion; (2) cost of locating leaks and (3) cost of gas lost due to the effect of corrosion.

Corrosion Supervisor

At headquarters office the corrosion supervisor originates the design and specifications for all new cathodic protection systems under the direct supervision of the superintendent of operations. The former also plans the general maintenance program. This includes (1) scheduling of pipe-to-soil potential measurements, (2) rectifier checks, (3) casing-to-pipe resistance measurements, (4) insulating flange resistance measurements, (5) calibration of pipe line to resolve current flow per millivolt drop, (6) magnesium current output measurements, (7) attenuation tests, (8) coating resistance measurements, (9) polarization tests and (10) joint interference tests with representatives from other companies (when conditions dictate).

At the headquarters office the corrosion supervisor has an assistant whose primary duty, besides that of assisting him is to assist corrosion personnel in the various division and district offices.

Division Corrosion Technician

Each division office has a division corrosion technician who reports directly to the division superintendent. His duties are to supervise and train district personnel in carrying out the various functions as mentioned above. The corrosion supervisor and his assistant work with the division corrosion technicians in carrying out their work and in training of district personnel.

Education and Training

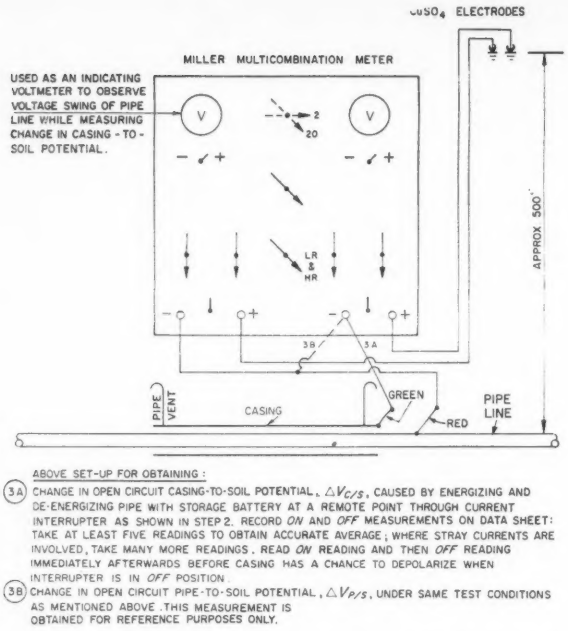
The education and training of district personnel, starts with a showing of the International Nickel Company's film "Corrosion In Action." The next step in explaining the use of meters and educating district personnel with regard to galvanic currents between dissimilar metals and the effects of cathodic protection is by means of a soil box demonstration. With small samples of copper, black iron pipe, galvanized iron pipe, bright iron pipe, rusty iron pipe, zinc, magnesium and corrosion instruments the mechanics of corrosion and cathodic protection can be demonstrated very simply and in terms that the laborer can understand.

Trans-Canada is cognizant of the fact that the success of a corrosion program and the savings resulting therefrom are directly proportional to the knowledge, experience and ability of its corrosion staff. To increase these qualities in division corrosion technicians, a company school of two months duration has been conducted during each of the last two years covering mathematics, electricity, corrosion and general planning for cathodic protection installations. This type of training or possibly some modification thereof probably will be continued. It is recognized that many years may be required to develop the technical background and experience required to solve corrosion problems.

It is easy for persons familiar with gas and mechanical engineering work to judge the soundness of engineering design and recommendations as made by personnel in this field. However, because of the comparative newness of corrosion investigations and techniques, an appraisal of cathodic protection design systems is not so obvious. Consequently, a company must rely on its corrosion men for good judgment in designs and recommendations. For this reason, it is essential that corrosion personnel be given broad experience on corrosion problems as soon as efficient training and time can permit them to absorb this knowledge.

Under the integrated system, the district man does both gas measurement and corrosion work. When not engaged in measurement or corrosion work, he performs his normal duties which may be maintenance or utility work having to do with either pipe line or compressor station.

The man chosen for this work should have at least a high school education, have an interest in electricity or be an electrician and have the ability to follow instructions. Initially, under the immediate supervision of the division corrosion technician or corrosion supervisor, he will be required to set up instruments, make electrical test connections to underground structures, read instruments, and record data. With experience, he will be expected to perform these functions by himself. He will be made responsible for the care and proper use of electrical instruments assigned to him. Through on-the-job training, he will be expected to acquire the knowledge of the use of voltmeters and ammeters as incorporated in

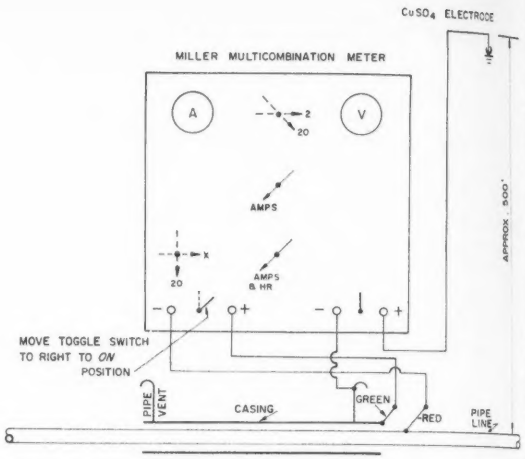


ABOVE SET-UP FOR OBTAINING:

(3A) CHANGE IN OPEN CIRCUIT CASING-TO-SOIL POTENTIAL, $\Delta V_{C/S}$, CAUSED BY ENERGIZING AND DE-ENERGIZING PIPE WITH STORAGE BATTERY AT A REMOTE POINT THROUGH CURRENT INTERRUPTER AS SHOWN IN STEP 2. RECORD *ON* AND *OFF* MEASUREMENTS ON DATA SHEET: TAKE AT LEAST FIVE READINGS TO OBTAIN ACCURATE AVERAGE; WHERE STRAY CURRENTS ARE INVOLVED, TAKE MANY MORE READINGS. READ *ON* READING AND THEN *OFF* READING IMMEDIATELY AFTERWARDS BEFORE CASING HAS A CHANCE TO DEPOLARIZE WHEN INTERRUPTER IS IN *OFF* POSITION.

(3B) CHANGE IN OPEN CIRCUIT PIPE-TO-SOIL POTENTIAL, $\Delta V_{P/S}$, UNDER SAME TEST CONDITIONS AS MENTIONED ABOVE. THIS MEASUREMENT IS OBTAINED FOR REFERENCE PURPOSES ONLY.

Figure 8—Check for casing short by resistance measurement (Step 3—of 3 to 5).

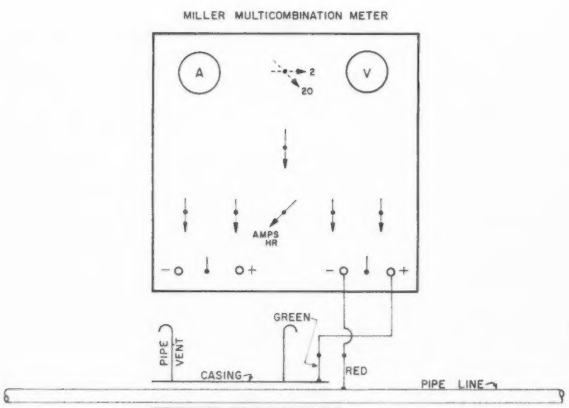


ABOVE SET-UP FOR OBTAINING:

(4A) CHANGE IN SHORT CIRCUIT CURRENT, ΔI_{SC}, CASING-TO-PIPE.

(4B) CHANGE IN CASING-TO-SOIL POTENTIAL, $\Delta V_{C/S}$, WITH CASING SHORTED TO PIPE THROUGH AMMETER.

Figure 9—Check for casing short by resistance measurement (Step 4—of 3 to 5).



ABOVE SET-UP FOR OBTAINING:

(5) CHANGE IN OPEN CIRCUIT PIPE-TO-CASING POTENTIAL, ΔV_{OC}.

$$\text{THEN, RESISTANCE PIPE-TO-CASING} = \frac{\Delta V_{OC}\,(\text{PER STEP 5})}{\Delta I_{SC}\ (\text{STEP 4A})} \times \frac{\Delta V_{C/S\,(\text{SHORT CKT})}\,(\text{PER STEP 4B})}{\Delta V_{C/S\,(\text{OPEN CKT})}\,(\text{STEP 3})}$$

Figure 10—Check for casing short by resistance measurement (Step 5—of 3 to 5).

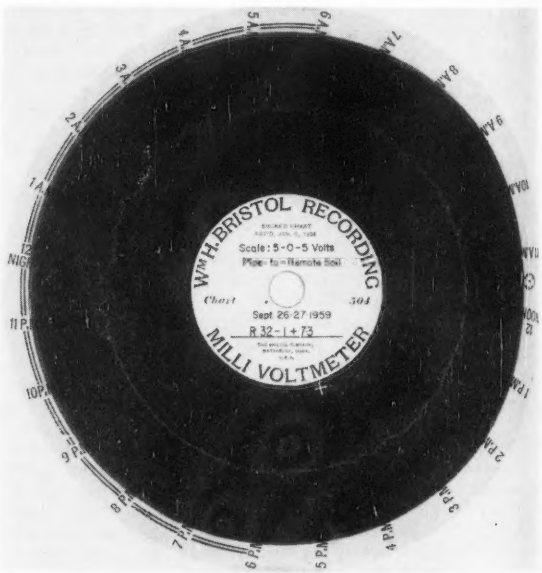


Figure 11—Recording chart illustrating effect of magnetic interference on pipe-to-soil potentials.

the Miller Multicombination Meter, current interrupter, copper-copper sulfate electrodes, pipe locators, rectifier tests and maintenance and other electrical equipment. He will be expected to become proficient in accurately reading the above meters and recording results on data forms for forwarding through his district superintendent to the division superintendent and on to the corrosion supervisor.

Although a certain amount of the man's work will be routine testing, the greater portion will be test work of an investigational nature. For example, he will frequently be working with the division corrosion technician in measuring coating resistance, calibrating pipe, making attenuation tests, polarization tests and other various tests as previously mentioned. His routine functions include pipe-to-soil potential measurements, rectifier readings and magnesium anode current measurements.

Installation Procedures

To assist the division corrosion technician and others from district personnel, typical drawings have been prepared covering recommended installation procedures and use of field test meters. As an illustration of this, Figure 2, shows a typical vertical ground bed installation. Figure 3 shows a typical horizontal ground bed installation, Figure 4 a typical vertical magnesium installation and Figure 5 a typical vertical single magnesium anode installation. As an illustration of step-by-step instruction procedure designed for use by the field man, Figures 6-10 show tests to determine if a casing is shorted to the carrier pipe and method

for measuring resistance between casing and carrier pipe.

Figure 6 shows a procedure for rough comparison method of determining if casing potential to earth swings when pipe is energized and de-energized. Figure 7 shows the interrupter set-up for energizing and de-energizing pipe line and Figure 8 the test procedure for obtaining change in open circuit voltage of casing to soil while energizing and de-energizing pipe line. Figure 9 shows test procedure for obtaining change in short circuit current by connecting pipe to casing through an ammeter and change in casing-to-soil potential as a result of energizing and de-energizing pipe line with this shorted condition. Figure 10 shows test procedure for obtaining change in open circuit voltage between pipe and casing while energizing and de-energizing pipe line and gives a formula into which data can be inserted to determine resistance.

In case there are variations in test readings due to magnetic earth currents, the measurement personnel are instructed to obtain many more readings for averaging-out purposes. Figure 11 shows recording charts illustrating effect of magnetic interference on pipe-to-soil potentials.

Trans-Canada's cathodic protection construction program functions through the division superintendents in a manner similar to that described for operating maintenance. The corrosion supervisor initiates the plans for rectifier construction with a letter to division superintendent requesting suggestions for location of rectifier ground bed sites along the pipe line that appear to be clayish and moist and are in the vicinity of power lines at approximately 25-mile intervals. For the most part division and/or district personnel will be sufficiently familiar with the line that such areas meeting these general requirements readily come to mind and can be pinpointed through review of alignment drawings. If no power is available, as is often the case, similar information as to likely sites for magnesium anode beds is welcomed. With this information and original soil resistivity measurements made during pipe line construction, the division corrosion technician with the help of district personnel, can proceed with 4-pin soil resistivity measurements in recommended areas with a minimum of time and effort. From these tests, decisions for location of rectifier units or magnesium anode groups are made.

Trans-Canada has a long pipe line to operate and maintain. It is anticipated that the corrosion preventive maintenance program will provide very low cost insurance against corrosion for many years to come and will simultaneously result in lower pipe line maintenance costs.

Any discussion of this article not published above will appear in the December, 1960 issue.

Technical Papers on Corrosion Welcomed

Authors of technical papers on corrosion are invited to submit them for review without invitation to the Editor of Corrosion. Write for "Guide for the Preparation and Presentation of Papers" sent free on request to prospective authors.

Sea Water Exposure of 70-30 Cupro Nickel Surface Condensers*

By H. A. TODHUNTER

Abstract

A report is given of research and development leading to the selection of 70-30 cupro nickel tubes and tube sheets and 70-30 cupro nickel lined waterboxes for 95,000 sq ft surface condensers in a steam plant. Topics discussed include design considerations, use of protective coatings, elimination of galvanic couples, resistance of metals to sea water, and economic factors.
7.4.2

Introduction

THE PURPOSE of this paper is to report the research and development leading to the selection of 70-30 cupro nickel tubes and tube sheets and 70-30 cupro nickel lined waterboxes for 95,000 sq. ft. surface condensers for Units 1 and 2 of the Los Angeles Department of Water and Power's Scattergood Steam Plant.

The condensers for Units 1 and 2 at this plant allow sea water to come into contact with only 70-30 cupro nickel. Both practical experience and engineering investigations dictated this choice.

The performance of condenser tubes and waterboxes in the Harbor Steam Plant were studied for several years. These studies indicated that a condenser designed with aluminum brass tubes and and steel waterboxes with a suitable lining would give low first cost equipment. However, the problem of finding a suitable lining for steel waterboxes and the difference in the expected life of aluminum brass and 70-30 cupro nickel tubes resulted in a choice of a condenser using 70-30 cupro nickel in contact with the sea water.

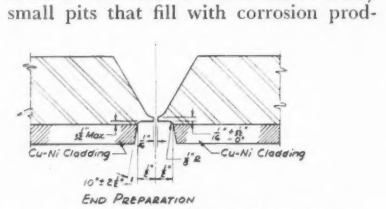
An organized search for metals and protective coatings which would better resist sea water corrosion was started in 1943. A test program in which several thousand condenser tubes were tested under actual operating conditions was begun in 1947.[1] In 1951, as a result of this test, it was tentatively concluded that 70-30 cupro nickel with an iron content of 0.4 to 0.8 percent was the most economical material for sea water condenser tubes.

In this test Admiralty, aluminum brass, aluminum bronze, 90-10 cupro nickel, 70-30 cupro nickel, and several other special alloys were tested. Condenser tubes with plastic coatings on the inside also were investigated and investigations of coatings for tube sheets, tube ends, and waterboxes are continuing. Several promising coating materials have been found; however, the special skills required for their application, the problems of making the equipment available for maintenance, the uncertainty of their durability, and the continuing costs of repeat applications have caused this search to continue.

The extensive corrosion of the cast iron waterboxes in condensers using brass tube sheets and tubes caused the graphitized surface of the cast iron to be cathodic to the brass sheets and tubes. The layer of graphite on the corroded surface of the waterbox offered some physical protection to the remaining cast iron. It also appeared to set up a galvanic couple with the tube sheets and tube ends causing galvanic attack on the brass. Cast iron with a coating of graphite was very difficult to cover with a protective coating and even more difficult if the graphite were removed and the surface made anodic to the tube sheets and tube ends.

Two new units were being designed. Their condensers were sized to give a turbine back pressure of 1.5 in. Hg. Abs. when using approximately 78,000 gpm of 60 F cooling water to condense about 750,000 lbs/hour of steam. A 95,000 sq. ft., single-pass condenser was selected with 40-foot long tubes and a 5-foot per second cooling water velocity. A 75 percent cleanliness factor was used for 7/8-inch OD by 18 BWG tubes.

An 83 percent metal transfer coefficient (in accordance with Heat Exchange Institute Standards) was used for the 70-30 cupro nickel. This results in about 13 percent more condenser than would be required for aluminum brass, the second most economical condenser tube material. Experience indicates, however, that after operating a few months the heat transfer rate of cupro nickel will equal or even exceed that of aluminum brass. This appears to result from the difference in corrosion action and protective film formed on the tube wall. The aluminum brass in the harbor water forms many small pits that fill with corrosion prod-

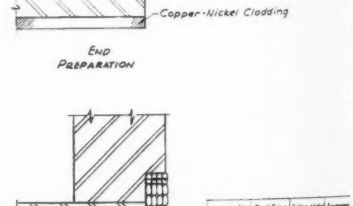

Cu-Ni Cladding
Cu-Ni Cladding
End Preparation
Carefully align lip edges and tack weld on steel side
Complete weld on steel side and complete hydrostatic test of waterbox before depositing nonferrous welds on plate joint
Complete penetration shall be obtained in the root pass of the steel weld
Cu-Ni Cladding
Cu-Ni Cladding
Grind smooth before welding layer No. 1
Welded End

Layer No.	Rod Size	Filler Metal	Amperage
1, 2	1/8"	Monel "Inco" 140	70-90
3, 4	1/8"	Cu-Ni "Inco" 137	70-90

Figure 1—Welding requirements for joining 70-30 copper-nickel clad steel plate.

Layer No.	Rod Size	Filler Metal	Amperage
1, 1a, 2	1/8"	Monel "Inco" 140	70-90
2a, 3, 4, 4a	1/8"	Cu-Ni "Inco" 137	70-90

Figure 2—Welding requirements for copper-nickel clad waterbox flanges.



Layer No.	Rod Size	Filler Metal	Amperage
1, 2	1/8"	Monel "Inco" 140	70-90
1a, 2a, 3, 4	1/8"	Cu-Ni "Inco" 137	70-90

Figure 3—Welding requirements for flanged openings.

About the Author

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★ Submitted for publication September 28, 1959.

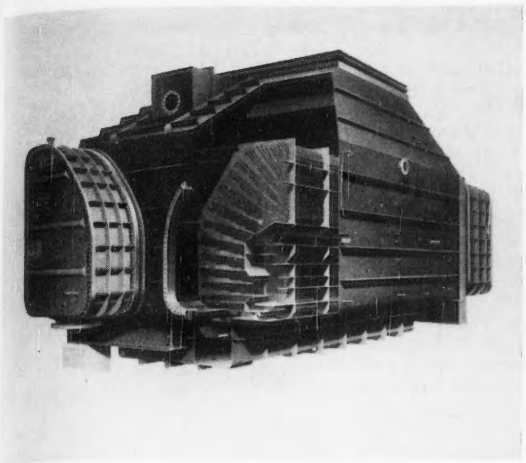

Figure 4—Artist's drawing of the condenser ordered.

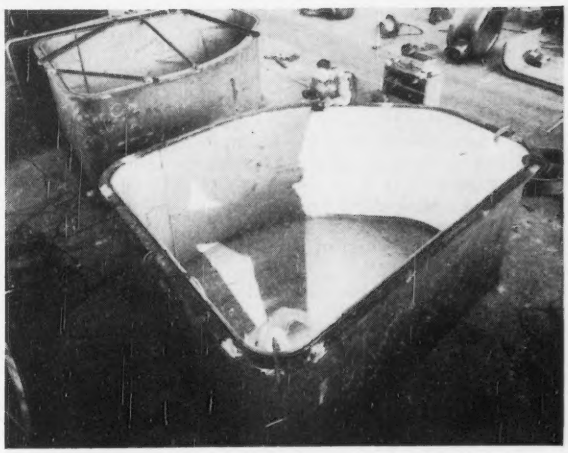

Figure 5—Cupro nickel lined waterbox during construction.

ucts while the cupro nickel retains a relatively smooth surface.

Non-condensibles were removed from the steam side of the condenser by a steam jet vacuum pump. Three 2-stage jets were used, each of which was designed for 9 cfm capacity. One larger jet was used for starting. Gases were removed from the waterboxes by wet-type rotary vacuum pumps.

The turbine back pressure and the cooling water requirements were arrived at by an evaluation of the entire circulating water system and the effect of vacuum on the turbine heat rate and capacity. The condenser was liberally sized to make it possible to keep the chlorine feed low and to avoid mechanically cleaning the tubes.

Design Considerations

In an effort to eliminate previous waterbox and tube end problems in the new condenser, an engineering search was made for a condenser that would be free from galvanic attack. Some of the designs available to accomplish this goal included:

1. A design using no dissimilar metals in the cooling circuit.
2. A design using cathodic protection to neutralize unfavorable galvanic action.
3. A design using protective coatings to dampen galvanic action.
4. A combination of two or more of the above schemes.

In order to evaluate these ideas, condensers employing the following designs were studied:

1. Condensers with cast iron waterboxes, 70-30 cupro nickel tubes and tube sheets, and cathodic protection using magnesium anodes.
2. Steel waterboxes with 70-30 cupro nickel tubes and tube sheets, with protective coating on the steel, and with electrical insulation between the 70-30 cupro nickel and the steel.
3. Condensers designed with 70-30 cupro nickel waterboxes, tubes, and tube sheets.

The first type condenser unit considered had cast iron boxes, 70-30 cupro nickel tubes and tube sheets, and cathodic protection. This condenser design was accepted for use as an alternate in condenser specifications. The shells for the waterboxes were specified six inches larger in cross section than the tube sheet drilling in order to provide room for anodes for cathodic protection.

As experience, up to this time, had not been good with protective coatings for cast iron in this service, no protective coating was included. The initial protective coating on Harbor Steam Plant, Units 3, 4 and 5 condensers lasted less than one year and the subsequent coatings were even less effective. The porous nature of cast iron causes it to be difficult to coat. The vacuum conditions under which these boxes operate also make coatings difficult to hold. By continually experimenting with plastic coatings as they are developed, techniques and skill are improving in this field.

However, the coatings applied just prior to the purchasing of the Scattergood Steam Plant condensers had not been very satisfactory. The technique at that time for coating waterboxes required sandblasting of the inside surface, followed by thorough drying by a hot air blast. After that, a heavy coat of polyvinyl chloride was applied cold by spraying. This formed a heavy, tough covering and at first appeared to be very effective. However, after a few weeks, large blisters, one inch or more across, started forming. These blisters appeared to be filled with gas which apparently was pulled out of the cast iron by the vacuum in the waterbox.

Recently, coatings of epoxy resins were found to protect cast iron waterboxes much more effectively. Such coatings, if skilfully applied to a new condenser, might last many years.

The second type condenser unit considered had 70-30 cupro nickel tubes and tube sheets with a waterbox made entirely of steel. A protective coating was required for all of the steel surfaces exposed to sea water, and the steel of the waterbox was to be electrically insulated from the cupro nickel. Such a protective coating would be more satisfactory if the steel waterboxes were completely insulated from the more noble tube sheets and tube ends as this would prevent the steel from acting as a sacrificial anode.

The plan to insulate the steel from the cupro nickel to prevent a galvanic couple from forming between these parts presented a complicated design problem. This electrical insulation was complicated because a thick insulating gasket would be required between the tube sheet and the waterbox flange, and the bolts holding the waterbox to the tube sheet would need to be completely insulated from these parts by an insulating sleeve around each bolt and heavy insulating washers under each nut. Such a design would require larger bolt holes and larger flanges. The heavy loading on the insulating parts also presented a difficult stress problem, and no satisfactory material for this service was decided upon. Because of these complications and an opinion that this design would result in a higher cost than the cast iron waterbox design, it was decided to omit this alternate from the specifications.

The third type condenser unit considered had 70-30 cupro nickel waterboxes, tube sheets and tubes. Since it was a design different from those previously used, specifications were prepared so that a cost comparison could be made between the new type cupro nickel waterbox design and the cast iron waterbox design in service.

The intent of this design is to furnish materials of about the same nobility for all of the surfaces exposed to sea water. The tubes recommended by the condenser tube committee are 70-30 cupro nickel with about 0.5 percent iron. This left the tube sheets and the waterboxes for detailed analyses. It was found that 70-30 cupro nickel tube sheets 1¼ inches thick would be as strong as Muntz metal tube sheets 1½ inches thick. This reduc-

tion in material weight partly compensated for the difference in material cost.

In studying the cost of more noble materials, such as Monel, stainless steel, and 70-30 cupro nickel for waterboxes, it became evident that these materials would be expensive to use. Cupro nickel cladded material offered a good compromise. The fabricated cost of 0.25 inch of cladding on 0.75 inch of steel was only a little more than the 0.1 inch of cladding on 0.9 inch of steel. As a result, 0.25 inch minimum thickness of cupro nickel cladding was specified.

Careful investigations were made to determine the iron dilution of cupro nickel which would be expected in the welded joints. It was determined that a weld with very little iron dilution in the last pass could be made if four passes were used in joining the 0.25 inch of cupro nickel cladding. These investigations showed that the iron dilution could be kept to less than 1.5 percent in the last pass. Figure 1 shows the procedure for butt welding the clad plate used in the waterbox construction.

The construction of flanges and nozzles also required special consideration. The main concern was for a surface that would have the same potential as surrounding surfaces and would be continuous. A surface built up by welding, as shown in Figures 2 and 3, was found to be satisfactory. Cladding by welding strips of cupro nickel to steel was not considered acceptable.

Cost Considerations

After a thorough comparison of the three types of waterbox designs, alternate specifications for price comparison were prepared for the first and third types, namely, the cast iron waterbox and the 70-30 cupro nickel clad waterbox designs. These specifications were advertised in the fall of 1955 and bids were received for both types of construction from seven bidders.

The bids were studied and a cost comparison was made. The low bid for the cupro nickel clad waterbox design evaluated 22 percent less over the life of the unit than the low bid for the cast iron waterbox design.

Figure 4 is an artist's drawing of the condenser ordered. It is designed for effective air removal from the steam side when either or both halves of the condenser are in operation. The drips from the colder section of the condenser and the air removal section receive special deaeration in the hot well. The large steam dome, which is designed for good steam distribution, houses the feedwater heaters for the two low pressure bleed points. These heaters, both in one shell, are located below the center of the double flow exhaust section of the triple flow turbine.

Figure 5 shows a cupro nickel lined waterbox during construction. The waterbox flanges, as shown in Figure 2, are faced with cupro nickel out to the bolt holes. From the bolt holes to the outer edge, carbon steel is used as it is not exposed to sea water. The faces of all other waterbox flanges are completely covered with cupro nickel.

Figure 6 is a view of the inlet end of the condenser in place. The opening in the dome is for the feedwater heaters, which were installed during erection. The cupro nickel tube sheets and clad waterboxes are shown being installed.

Tests on the Unit No. 1 condenser under actual operating conditions showed that it performed considerably better than the Heat Exchange Institute (HEI) requirements and about as expected. The clean heat transfer rate at the rated steam flow averaged 653 Btu/sq ft/deg F, which is about 30 percent above HEI. The fouled heat transfer rate after a few days of service averaged 500 Btu/sq ft/deg F about 33 percent above the design point—75 percent clean. After about one month's additional operation, the heat transfer rate at rated steam flow dropped to a steady rate which was about 27 percent above the design point.

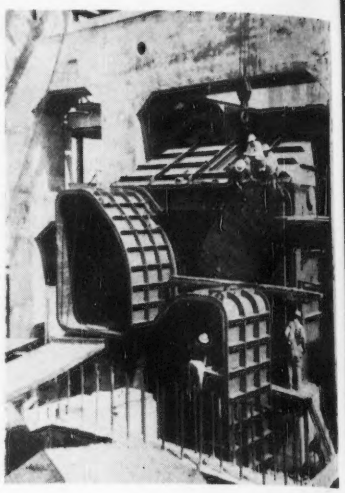

Figure 6—View of inlet end of condenser in place.

The excellent performance of this condenser is attributed to its open steam lanes and to the thin, smooth corrosion film on the 70-30 cupro nickel tubes. The condenser waterboxes, tube sheets, and tube ends when inspected after about five months of service, were found to be in excellent condition.

Reference

1. H. A. Todhunter. How to Lengthen Condenser Tube Life. *Power*, 85 to 87 (1956) Mar.

Any discussion of this article not published above will appear in the December, 1960 issue.

Autoclave Testing of Zirconium Alloys*

By O. FLINT

Introduction

ZIRCALOY 2[1] corrodes slowly when heated for long periods in 320 C water at 1700 psi. It shows weight gains of the order of 0.3-0.5 mg/cm²/year (equivalent to a corrosion rate of 0.01-0.02 mils/year of metal to oxide).[1,2] Corrosion of the alloy in high temperature water is often characterized by a period of decreasing rate, of varying length, followed by a sudden transition to a linear rate, these factors being dependent on the quality and condition of the material under test. For example, the conditions which affect the onset of the transition to a linear corrosion rate are diverse and would seem to be related to impurities (e.g., nitrogen, carbon, or aluminum, cold working and various surface treatments.)

To maintain the corrosion rate at a minimum it is common practice, before using or testing the alloy, to prepare a "standard" surface; this entails the removal of insoluble scale by shotblasting with 120 mesh steel grit and pickling for two minutes in a 45 percent nitric-5 percent hydrofluoric acid solution. This treatment reduces metal thickness by approximately 0.002 inch and is said to eliminate the disturbed region responsible for observed accelerated corrosion rates.[2,3,4,5]

Many effects on the corrosion of the alloy in high temperature water are attributed to alloy condition, composition and history.[2,3,4,6,7] Surface preparation of the metal has not been studied in any detail by previous workers other than Cox,[8] who recently and independently arrived at some of the conclusions on the effects of surface preparation shown in this report.

In this work a polished surface, taken as an arbitrary control, was compared with "as drawn," pickled, anodized and welded finishes. Gaseous surface treatment with hydrogen and nitrogen was also examined and the effect of nitrogen as a contaminant in depth was investigated by testing specimens with varying concentration of this element. Finally specimens, corroded beyond the transition point, were cleaned and retested to demonstrate the effect of specimen history on the process.

Experimental Procedure

For the tests involving surface preparation, specimens of Zircaloy 2 tube ¼ inch long by 1 inch diameter and 0.040 inch thick from two different ingots were used. Analyses of these tubes and of the other materials tested in this work are given in Table 1.

After various surface preparations, described below, specimens were suspended on ceramic hooks,[2] on a stainless steel jig inside an 18-8-1, titanium stabilized stainless steel autoclave containing demineralized water of pH ~ 6.5. The water was changed for each test and no attempt was made to purge nitrogen from the autoclave atmosphere or water at the start of any run. The autoclave technique and temperature control are described in a previous report by Britton and Wanklyn.[4] After each test run the autoclave was opened slowly to release any hydrogen formed as a result of corrosion[3] and the specimens were dried at 120 C in an oven, brushed with a camel hair brush and weighed.

Surface Preparation

A brief description of the surface preparations tested is given below.

Polished surface. The metal was mechanically polished by grinding on an emery wheel (dressed with 120 grit), followed by bobbing with grease bound chromic oxide (approx. 400 mesh) and buffing with Vienna lime; 0.003 inch metal thickness was removed in the process. Alloy 1 (Table 1) was used for these tests and specimens were degreased with acetone before use.

Surface "As Drawn." The tube as fabricated (Alloy 2, Table 1) was covered with a matt black scale and was used for tests in this condition, after grease removal with acetone. Experiment showed this scale to be soluble in the standard nitric-hydrofluoric acid pickle on the inside of the tube only. This may be due to film formation in a restricted oxygen atmosphere, during extrusion on the inside of the tube, a film which, being unsaturated, could be expected to have a greater reactivity.

Mild pickle. Material in the "as drawn" condition (Alloy 2, Table 1) was degreased and rumbled in water with 80 grit carborundum for 16 hours to remove scale and then pickled in a solution of 3 percent sodium fluoride and 1 percent ammonium chloride in normal sulfuric

About the Author

OLIVER FLINT is a senior experimental officer at the Atomic Energy Research Establishment, Harwell, England. He is an associate of the Royal Institute of Chemistry, and has been employed during the past 22 years on problems connected with electrodeposition and the corrosion of metals.

Abstract

No significant difference between water corrosion of American and British Zircaloy-2 at 320 C is observed when corrections for variations in autoclave testing techniques are made. Nitrogen contents up to 220 ppm can be tolerated in British Zircaloy without acceleration of attack. Mechanical polishing or the conventional nitric-hydrofluoric acid pickle, as pre-treatments prior to testing, appear to be equally efficient in minimizing corrosion effects. Welding does not impair corrosion resistance, provided the weld is "bright" as made and surface polished.

A retest of material already taken beyond the transition point at which Zircaloy 2 corrosion rates become linear showed the characteristically low initial rate of the alloy control specimen in spite of the high hydrogen concentration generated in the first test. 6.3.20

* Submitted for publication April 27, 1959.

(1) An alloy of zirconium with 1.5 percent tin and additions of iron, chromium and nickel.

(2) Al_2O_3

(3) Failure to open autoclaves slowly leads to ignition of the contained gas and, where corrosion has been extensive, to explosions.

TABLE 1—Analysis of Materials Tested*

Alloy	Sn	Fe	Ni	Cr	Al	C	Si	Pb	N_2	O_2	Cl	H_2
(1) Polished Zircaloy 2 Tube British	1.6%	820	280	495	130	1600	75	45	85	275	30	55
(2) "As Drawn" Zircaloy 2 Tube British	1.5%	990	435	440	1200	....	70	..	390	...	20	....
(3) Zircaloy 2 laboratory prepared stock for nitrogen alloys	1.55%	1200	365	750	....	400	..	..	130	...	..	....
(4) A. G. 29												
(a) "Post-transition" specimen	1.5%	600	300	500	....	....	..	..	1210	...	..	1450
(b) Control specimen	1.5%	600	300	500	....	....	..	..	1210	...	..	70
(5) American Zircaloy 2 Nominal analysis (Lustman (11))	1.5%	1200	500	1000	50	....	..	..	60	...	..	....

* All elements expressed in ppm with the exception of Sn.

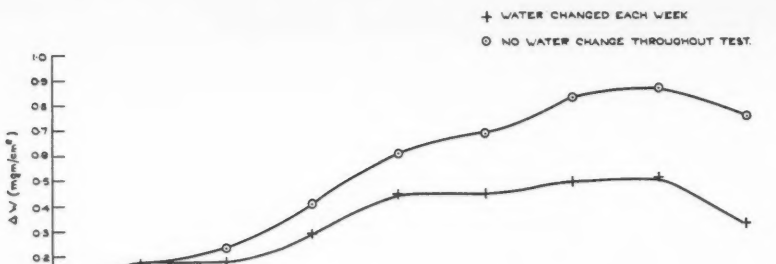

Figure 1—Variation of corrosion of Zircaloy-2 with autoclave test technique.

TABLE 2—Observed Corrosion Rates for Various Surfaces*

Sample	Number of Specimens Tested	Slope Before Inflection	Slope After Inflection	Time to Inflection (Days)
Polished	5	0.300	.....	~160
"As drawn"	2	0.415	.....	.....
Mild Pickle	2	0.730	.....	.....
Anodized	4	0.541	.....	~240
Welded	2	0.361	.....	.....
A.G. 29 "Post transition"	1	0.661	.....	.....
"Control"	1	0.663	1.225	~ 50
5 & 10 hrs. in hydrogen at 320 C	4	0.255	.....	.....
Moist N_2 at 400 C	2	0.200	.....	.....
All nitrogen alloys	5	0.500	.....	.....
American alloy at 288 C	Uncorrected	0.365	.....	.....
(Lustman (11))	Corrected	0.474	.....	.....
American alloy at 360 C	Uncorrected	0.347	1.650	~100
(Lustman (11))	Corrected	0.450	1.030	.....
British alloy	Uncorrected	0.277	0.775	~200
Standard Pickle (Britton & Wanklyn (4))	Corrected	0.462	1.19	.....

* All slopes corrected to **NO WATER CHANGE** for standardisation.

acid, at room temperature for 5 minutes. This treatment removed 0.001 inch wall thickness and was designed to be less rigorous than the standard nitric-hydrofluoric acid pickle.

Anodized surface. Alloy 2 (Table 1) was shot blasted and pickled in the standard way. It was anodized at room temperature in 2 percent ammonium borate solution at a constant current density of 2.5 ma/cm². Formation potentials of 20, 50, 75, and 100 volts were reached on different specimens giving interference colors equivalent to film thickness of 400, 1,000, 1,500 and 2,000 Å respectively. The method used and thickness estimations are fully described in the literature.[9]

Welded surface. Two clean samples of Alloy 1 (Table 1) tube were butt-welded in an atmosphere of pure argon, as described by Purchas et al.[10] The weld so formed was bright with a large grain size (~ 1 mm) in the melted zone. Contamination of the welding gear or atmosphere with grease, oxygen or nitrogen gives rise to black welds with poor corrosion characteristics.

Post "transition" retest. A specimen previously autoclaved to beyond the transition point at which linear rates occur (Alloy 4a, Table 1) and having a buff colored loose oxide skin, was shot blasted and pickled in the standard nitric-hydrofluoric acid pickle. This specimen of laboratory melted and rolled sheet had a high nitrogen content. A comparison was made between Alloy 4a and a specimen of the virgin material, Alloy 4b, prepared in a similar manner.

In addition to the test surfaces described, specimens of Alloy 1 (Table 1) were heated in hydrogen and nitrogen at 320 C and 500 C respectively for varying periods to estimate the effect of such gaseous annealing on subsequent corrosion. The temperatures chosen represent the lowest at which appreciable uptake of the gas might be expected to occur.[11]

To investigate the effect of nitrogen impurity in depth rather than as a surface skin, alloys containing various concentrations of nitrogen were prepared by argon arc melting Zircaloy 2 (Alloy 3, Table 1), with zirconium nitride[(4)] in proportions calculated to give a range of five alloys containing 100-1,000 ppm nitrogen. Losses during melting prevented this and analyses gave 165, 205, 210, 220 and 225 ppm nitrogen respectively. Buttons of these alloys were sliced, drilled for suspension, pickled in the standard pickle and tested to determine the nitrogen concentration at which transition to a linear rate occurred.

Autoclave Technique

During autoclave tests, corrosion of the stainless steel bomb wall frequently contaminates the contained water with chromium;[12] ferric hydroxide is also formed as a result of this attack, and precipitation of this on the specimen may take place and give rise to confusing results.[8] This observation prompted the decision to make a water change after each specimen examination during a run. In spite, or because of this precaution, an anomolous decrease in weight with time in the first sixty days was observed in almost every case irrespective of the type of test involved.

As the variations appeared to be associated with frequency of specimen examination, two individual sixty day runs were made using polished alloy 1 (Table 1) as test material. The specimens (3 in each bomb) were weighed weekly, with a water change per examination in one bomb but not in the other. These results

(4) The zirconium nitride used was in the form of small, acicular, golden yellow crystals.

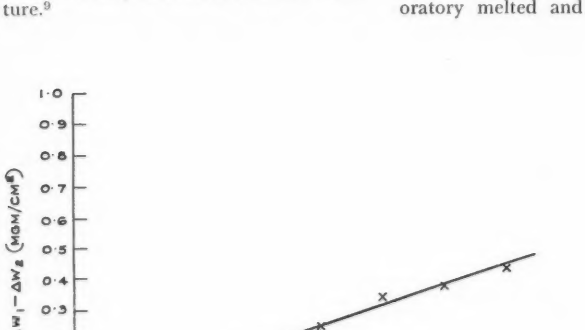

Figure 2—Correlation between water change and weight variation.

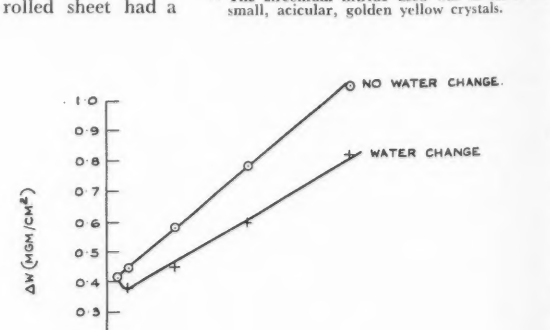

Figure 3—Corrosion of polished Zircaloy-2 in water at 320 C.

together with those on surface corrosion are reported below.

Results

Autoclave Technique

The weekly variation in weight of Zircaloy 2 in fresh and in unchanged water is shown in Figure 1. A lower over-all weight increase over the test period in fresh water suggested some dissolution of the film during formation rather than a precipitation of the bomb wall contaminants. A linear relationship (Figure 2) obtains between this difference in weight change and the number of water changes. From the curve a weight loss of 0.0614 mgms/cm² per water change is deduced and this factor is incorporated in subsequent results as a correction.

Since the water charge per bomb has a volume of 120 cc, this indicates a dissolution limit of $\frac{1}{2} \times 10^{-6}$ gms/cc, set by the solubility product of zirconium oxide in water at the test temperature of 320 C. Analysis of water charges gives a zirconium content of this order of magnitude.

Surface Treatments

Polished surface. Figure 3 shows the variation in weight of polished Zircaloy 2 with time, in water at 320 C, and also the corrected variation assuming that no water change took place between each examination. The anomalous dip in the curve in the first 20 days, associated with the solubility of the metal oxide in water, is removed by the correction and a linear rate is then observed. Assuming that the oxidation of Zircaloy 2 follows a rate law of the form $W = kt^n$, then a log/log plot gives the slope of the corrected curve as 0.30. This rate is in good agreement with Lustman's figure[11] for American Zircaloy 2 of 0.365 (uncorrected), or 0.474 (corrected), as shown in Table 2 despite the differences in quality of the two alloys. The two rates are given because it is not clear from the literature whether American practice dictates a water change per specimen examination.[2]

There is no evidence from these results that the transition to a linear rate in British Zircaloy 2 is accelerated by the omission of the standard nitric-hydrofluoric acid pickle. A comparison between the two alloys when pickled is made later (see Figure 6).

Surface "as drawn." Zircaloy 2 in this condition (Alloy 2, Table 1), proved to have a surface scale which was loosened by autoclave conditions. This produced an initially high weight loss in the first week (2 mg/cm²) followed by a continuous but small loss over the test period. Figure 4 shows this variation, corrected from observed loss to equivalent weight gain. With this correction, an oxidation rate of 0.415 is found from a log/log plot (Table 2). This is still well below the transition to a linear rate in spite of the fact that no preliminary surface preparation had been made and that the bulk nitrogen content of this alloy is high (390 ppm).

Mild Pickle surface. This form of preparation produced a rougher surface than that formed in the standard pickle and the relatively high corrosion rate of 0.730 (Table 2) was observed. This high rate may be due to the absorption of fluoride ions on the rough surface left by the tumbling pretreatment.[2, 12]

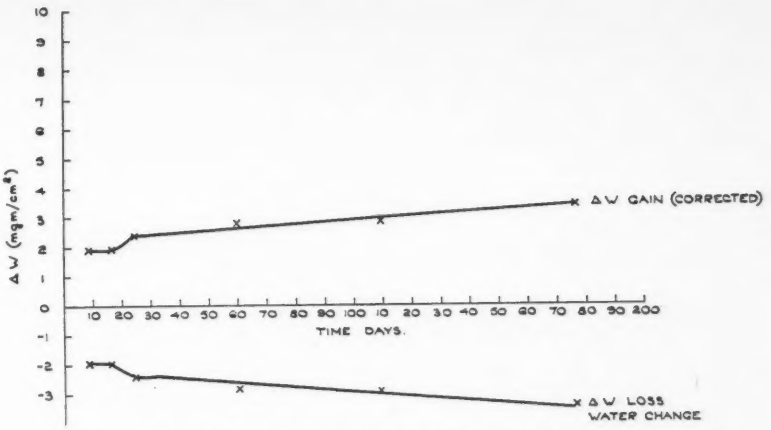

Figure 4—Corrosion of "as drawn" Zircaloy-2 in water at 320 C.

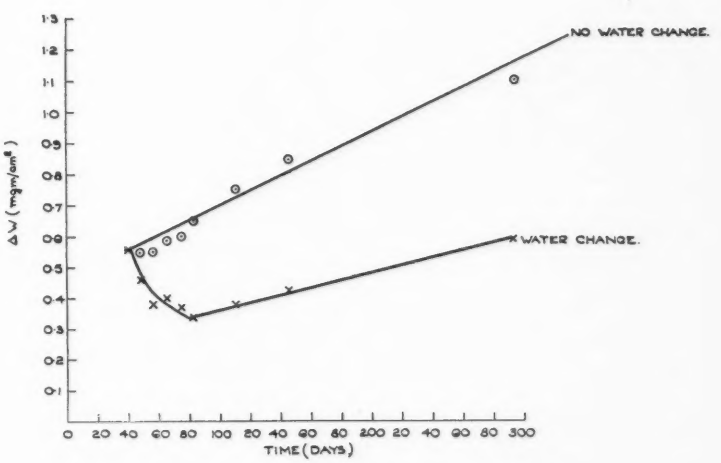

Figure 5—Corrosion of welded Zircaloy-2 in water at 320 C.

Anodic oxide surface. This surface pretreatment made no significant difference to the oxidation behavior during the autoclave test. Irrespective of oxide film thickness formed, a rate of 0.541 was observed, which is slightly higher than the polished control surface (see Table 2).

Welded surface. These results are a good example of the water change effect. By chance the first examination and change of water took place after 40 days and there were 5 subsequent water changes in the next 40. Figure 5 shows plots of weight increase with time, both with and without water change. Within the limits of experimental error a linear plot is produced by the correction and an oxidation rate of 0.361 (Table 2) is obtained. Thus welding has no apparent effect on the corrosion of the alloy.

Post "Transition" retested surface. The rate of oxidation of the freshly pickled "post transition" specimen and of its control were substantially the same (see Table 2). Therefore no "memory effect" was observed, although the hydrogen content of the retested sample, before the second test was 1450 ppm compared with 70 ppm for the AG 29 control (Table 1). This concentration of hydrogen does not appear to influence further corrosion of a fresh surface. The high over-all rate of oxidation for AG 29 stock (Alloy 4, Table 1) is due to an excessive nitrogen content of 1210 ppm.

Heat treatment of Zircaloy 2 (Alloy 1, Table 1) in both hydrogen and moist nitrogen at 320 C and 500 C respectively for varying periods gave similarly low rates of oxidation. As the two gases and the conditions are so different the reason behind this reduction in rate is not obvious but it may be due to (a) a low concentration of oxygen (always present as a gaseous impurity), or to (b) hydrogen diffusion from the gas or dissociated water (present in the moist nitrogen test).

One exception to the above was given

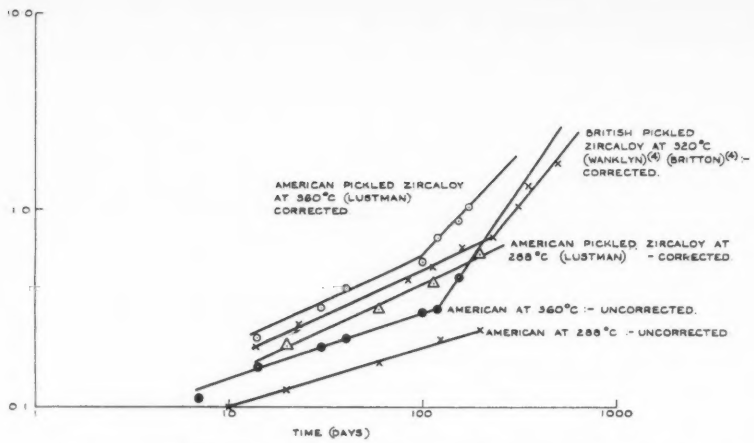

Figure 6—Comparison of British and American Zircaloy corrosion showing transition point. The term "Lustman" in graph refers to Reference 11.

by the alloy when heated for 40 hours in hydrogen at 320 C. In this case the metal became brittle, absorbed 0.14 percent by weight hydrogen and on autoclaving gave a weight increase of 6.5 mg/cm² in the first eight days, which left the sample covered with a loose white film, a condition found well beyond the transition point. A micro-section showed that a great part of the material was in the form of hydride.

Finally, the results of nitrogen contamination in depth gave similar plots, from 165 to 225 ppm concentration. The rate of oxidation (when corrected for water change) was 0.5 (Table 2), a little higher than the polished control (0.3). No evidence of transition to a linear rate was observed after 200 days in any alloy.

Discussion

It seems, from the results quoted above, that a pretreatment of Zircaloy 2 in nitric-hydrofluoric acid, after shot-blasting, is not essential to maintain low rates of attack or to postpone the transition to a linear corrosion rate. The composition of the alloy can also vary within wide limits without acceleration of attack. Further weight can be given to these conclusions when the results from unprepared material in factory condition are considered. Even in this case, early transition to a linear rate of attack does not seem to occur. Similar results with ground and metallographically polished surfaces have been found by Cox,[8] independently of this work, on material of different composition.

The similarity of attack of welded and polished surfaces provides a result of technological importance since the inference here is that initial clean bright welds (argon arc) are unlikely to be failure sites in high temperature water systems. The retest of material already corroded beyond the transition point demonstrates that repreparation of the surface halts the accelerated attack and that the inherent corrosion of the alloy does not depend therefore on its earlier corrosion history.

The importance placed by previous workers on nitrogen content appears to have been over-emphasized for Zircaloy 2 in the light of results given above. The practical limits of nitrogen concentration seem much higher than the nominal 60 ppm quoted in the literature.[11] With British material, up to 220 ppm nitrogen can be tolerated without undue acceleration of attack (see Table 2), and this relaxation should reduce the production costs of the alloy considerably.

Finally, Figure 6 shows a comparison of results between American and British Zircaloy 2 plotted on a log/log scale. In the top three curves the "water change" correction has been made. Apart from the fact that "transition" occurs sooner at higher temperatures the results all show a similar rate and magnitude, irrespective of temperature or alloy source. If, however, this correction is not made, as in the bottom two curves for American Zircaloy 2, a much lower attack appears to have taken place. In the light of the corrections it is suggested that American and British Zircaloy 2 are essentially identical in behavior since any differences could result from variations in autoclave technique.

Conclusion

Because a direct influence of experimental technique on the corrosion of Zircaloy 2 in autoclaves is shown by this work it becomes clear that previous results should be reassessed before final conclusions as to alloy corrodibility are made.

Furthermore, some control on corrosion rate, exercised by surface finish, is revealed. A nitric-hydrofluoric acid pickle before high temperature water testing is not imperative, since similar minimum corrosion rates can be arrived at by polishing only, without the increased danger of accelerated attack due to absorbed fluoride ions, retained after pickling. This work also shows that transition" to a linear rate of attack is not a "once for all" phenomenon, as no "memory" effect was shown by retesting cleaned material after initial failure.

The fact that nitrogen contents up to 220 ppm can be tolerated in British Zircaloy 2 without seriously affecting corrosion resistance is of interest, since a relaxation of fabrication control, in this direction, will materially lower production costs.

Acknowledgments

The author wishes to thank Drs. J. E. Antill and J. H. O. Varley for much useful discussion, and Dr. H. M. Finniston for his encouragement throughout the work. On the experimental side he would like to thank C. Britton and J. T. Demant for their help with some of the autoclave tests and H. Lloyd for the preparation of the nitrogen alloys.

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Any discussion of this article not published above will appear in the December, 1960 issue.

NATIONAL ASSOCIATION of CORROSION ENGINEERS

Cathodic Protection of Hulls And Related Parts

A Report of NACE Task Group T-3G-1* On Cathodic Protection of Hull Bottoms of Ships

NACE TECHNICAL COMMITTEE REPORT
Publication 60–7

Abstract

A summary is made of information known about cathodic protection of ship hulls and related parts. Problems involved in the cathodic protection of hulls are outlined and factors which influence protective current requirements are given. Data reported include protective potentials of steel hulls measured against four reference electrodes, advantages and disadvantages of the sacrificial anode vs the impressed current anode, and properties of magnesium, zinc and aluminum galvanic anodes. 5.2.1

Introduction

ALTHOUGH THE cathodic protection principle has been applied to hulls in the form of zinc plates for more than 130 years, there is now a rapidly developing interest in the use of impressed current and galvanic current sources to control hull corrosion.

NACE Task Group T-3G-1 was organized to outline the problems, to summarize information now known and to establish recommended practices for the cathodic protection of hulls.

The initial report of the task group is presented for guidance and outline for future work.

Application

Cathodic protection can be successfully applied to prevent corrosion on the exterior underwater areas of all steel hulled vessels. The scope of this application includes all metal vessels operating on or below the surface of the water, both moving and stationary.

The term "hull" in this report means the exterior surface of any object used in marine service for the primary purpose of maintaining or regulating buoyancy, including all parts required in its function.

Cathodic protection can be successfully applied to metals other than steel. However, because of the possibility of causing cathodic corrosion of certain non-ferrous metals, the cathodic protection of non-ferrous metal systems should not be attempted without the close supervision of a qualified corrosion engineer.

Where one hull is to be cathodically protected and this hull is in close proximity to other hulls or metal structures to which protection is not being furnished, the hull to be cathodically protected must be electrically isolated from the other hulls and metallic structures.

The design of the protective system should be supervised by a qualified corrosion engineer to provide proper current distribution, to control the applied current, to prevent excessive coating damage and to guard against harmful stray current effects.

Where a group of hulls are to be cathodically protected from a single cathodic protection system, all hulls to be protected must be electrically bonded to each other. The group of hulls under protection must be electrically isolated.

In cases where the hull or part of the hull is subject to frequent intermittent exposure in the water, cathodic protection cannot be considered 100 percent effective in preventing the corrosion that occurs in the atmospheric exposure part of the cycle.

Measurement of Protection

The protective effect of applied current on a hull can be established by measurement of the hull potential against a reference electrode, periodic comparison of the hull plate dimensions and/or by examination of products on the hull.

The application of protective current in an amount too small to provide complete protection will still result in partially reduced corrosion on the hull.

Hull To Reference Electrode Potentials

Nearly all metals in sea water are protected when the potential of the corroding surface is shifted by at least 100 millivolts in the electronegative direction.

Substantially complete corrosion control is achieved on a steel hull when it is polarized to a potential of —.78 volt or more electronegative measured against a saturated KCl calomel reference electrode (or its equivalent) positioned at the point of interest on the hull surface.

The potential of a non-moving hull can be measured against a reference electrode lowered or keelhauled to the points of interest. Example: Position the reference electrode in close proximity to the rudder, stern frame, etc., when cathodic protection current is applied from anodes located in the stern areas.

The potential of a moving hull can be measured against reference electrodes secured to the hull at the selected points of interest. The potential of hulls receiving overall cathodic protection from distributed anodes may be measured against a trailing reference electrode (50 feet or more behind the vessel). The potential measured with a trailing electrode should be correlated with the potentials measured at representative hull surfaces.

The protective potentials of steel hulls measured against four different reference electrodes are tabulated in Table 1.

Permanently attached reference electrodes should be selected for the water in which the hull operates. The electrode should require no "foreign" electrolyte to maintain the specified concentration. This requirement usually leaves the choice of two electrodes, either silver-silver chloride or zinc.

Comparison of Plate Dimensions

A direct measure of the corrosion rate on a hull may be established by compari-

TABLE 1—Protective Potentials of Steel Hulls Measured Against Four Reference Electrodes

Reference Electrode	Electrolyte	Protective Potential, Volts
Calomel	Saturated KCl	—.78[1]
Ag-AgCl	Sea Water	—.81[2]
Copper	Saturated $CuSO_4$	—.85[3]
Zinc (MIL-A-18001)	Sea Water	+.25[4]

[1] The protective potential becomes more electronegative as the KCl solution is diluted.
[2] The protective potential becomes more electronegative as the sea water is diluted. Example: The protective potential is about .06 volt more electronegative when the Ag-AgCl electrode is in equilibrium with brackish sea water—1 part sea water and 9 parts fresh water.
[3] The protective potential becomes less electronegative as the copper sulfate solution becomes contaminated with sea water.
[4] The salinity of the water has very little effect on the protective potential and age will change it no more than 20 mv. It is capable of delivering small currents without polarization.

*L. P. Sudrabin, Electro Rust-proofing Corp., Newark, New Jersey, chairman.

TABLE 2—Comparison of Cathodic Protection Systems

Type of System	Advantages	Disadvantages
Sacrificial galvanic anode	Self contained electrical source	Generally, when available, an outside source of current is less expensive than current generated by anodes.
	Needs little supervision—protective current always flows in the right direction.	Connection resistance greatly affects anode output in sea water.
	Simple to install.	Usually not economical for fresh water sites where large current demand prevails.
	Anode leads are cathodically protected where exposed and do not require insulation.	Greater weight and bulk than for impressed current system.
Impressed current anode, sacrificial and non-sacrificial	Protective current can be adjusted manually or automatically.	More difficult to install and operate.
	Lighter weight, fewer anodes necessary.	System vulnerable to electrical and mechanical damage.
	Current from an outside generated source usually costs less than current obtained from galvanic anodes.	Closely coupled anodes require dielectric shields.
		High initial cost.
		An outside source of electrical power is needed.
		Anodes and lead wires must be insulated from the hull.

TABLE 3—Properties of Galvanic Anodes

Property	Magnesium	Zinc (MIL-A-18001-D)	Aluminum (Alcoa B605 or Equiv.)
Composition	Al-5.0-7.0 Zn-2.0-4.0 Mn-0.15 Min. Si-0.1 Max. Cu-0.1 Max. Fe-0.003 Max. Ni-0.003 Max.	Pb-0.006 Max. Fe-0.0014 Max. Cd-0.004 Max. Cu-0.005 Max. Al-0.1 Min.	Zn-5.0-6.0 Fe-0.17 Max. Cu-0.02 Max. Si-0.10 Max.
Nominal Solution Potential (Ag-AgCl volts)	1.5	1.05	1.0
Driving Potential to a polarized cathode —0.81 V. (Ag-AgCl)	0.69	0.24	0.19
Typical current capacity ampere-hours per pound	500 at 50 Percent Efficiency	355 at 95 Percent Efficiency	725 at 53 Percent Efficiency
Actual anode consumption at above efficiencies, pounds per ampere year	17	25	12
Density—pounds per cubic inch	0.063	0.258	0.10

son of the records of selected pit depths or of the plate thickness at successive drydockings.

The pit depth measurements must be repeated at precisely the same location (photographic records are helpful). Plaster casts of the pits will record the pit contour and allow both visual examination and physical measurement of the pit.

The progress of general bottom corrosion, as when activated by repeated passage over sand bars, may be established by comparison of non-destructive thickness measurements (audigage) over a six month period. These measurements may be made while the vessel is in water from prepared polished surface test stations located within the hull.

Examination of Products on the Hull

It has been established that the active corrosion products in pits have a pH less than 6.0 (sometimes as low as 2.0).

Corrosion control is virtually complete when the pH of products in pits exceed 9.0. Another indication of control of corrosion in pits is the presence of calcareous salts precipitated by the alkalinity produced in the salts by the cathodic process.

Sources of Protective Current

Current for the protection of a hull may come from two (2) general sources: externally generated current and current produced by galvanic action where the hull acts as a cathode of an electrolytic cell.

The hull surface does not recognize the nature of the source of the protective current. Thus, economic and practical conditions will determine the best protective system to use. Advantages and disadvantages of the various systems are outlined in Table 2.

Externally generated current can be produced by rectifiers, motor generators or batteries. Motor generators are usually used where there is only DC power available. Dry plate type rectifiers or motor generators are used on ships with AC power.

The types of impressed current anodes presently used on hulls include graphite, platinum and platinum alloys (non-sacrificial) and iron (sacrificial), and silver-lead alloy.

The types of galvanic anodes presently in use are aluminum, magnesium and zinc. Properties of galvanic anodes are given in Table 3.

Use and Influence of Coating Systems on Cathodic Protection

Protective coatings reduce the hull metal surface area exposed to the environment and decrease the protective current requirements.

The ideal protective state to be maintained on a coated hull is to assure corrosion control at any exposed area on the hull without applying an excess of current which will accelerate coating deterioration. The applied current should be regulated to maintain the minimum protective potential of —.81 volt measured against a silver-silver chloride reference electrode placed at the coating surface. The potential measured should not exceed —1.0 volt. Coatings, used in combination with cathodic protection, should be unaffected by cathodically produced alkali, should retain adhesion and should have a high electrical resistance.

Proper shielding should be used with all types of anodes.

Factors Which Influence Protective Current Requirements

The protective current requirements vary from hull to hull and from time to time. Generally, factors which reduce corrosion will reduce the protective current requirements. The protective current requirements for mild steel hulls in sea water range from .1 ma/sq. ft. for well coated surfaces to over 100 ma/sq. ft. for hull surfaces activated by repeated abrasion by passage over sand bars.

Factors Which Reduce Protective Current Requirements

1. High resistance coatings on the hull.
2. Presence of deposits: precipitated calcareous salts, fouling organisms and corrosion products.
3. Reduced temperature.
4. Absence of velocity effect including vibration.
5. No propellers or other cathodic metal coupled to hull.

Factors Which Increase Protective Current Requirements

1. Low resistance coatings.
2. Absence of deposits.
3. Removal of polarization products by mechanical means.
4. Increasing velocities or vibration.
5. Increased temperatures.
6. Bronze propellers and other cathodic surfaces coupled to hull.

New Developments in Cathodic Protection Rectifiers*

By HARRY R. ASCHAN

About the Author

HARRY R. ASCHAN is Chief Engineer of the Electrical-Mechanical Division of Good-All Electric Mfg. Co., Ogallala, Nebraska, where he is in charge of design and production of cathodic protection rectifiers. Mr. Aschan served in the U. S. Navy as an Electronics Technician and was employed for 1½ years by Schlumberger Well Surveying Corp. as Field Engineer. He received a BS in mechanical engineering (1950), a BS in electrical engineering (1951) and a Masters Degree in electrical engineering, all from the University of Illinois. He holds a professional engineer's license in the State of Illinois, and is a member of Tau Beta Pi, NACE, AIEE, and National Electrical Manufacturer's Association.

Abstract

A review is made of recent developments in cathodic protection rectifiers. The most significant of these changes is the development of high voltage selenium and silicon rectifying elements and the use of these elements in circuits which are new to cathodic protection. This results in rectifiers which are more efficient, less costly, lighter, smaller, and lower in maintenance cost. Other changes in rectifier materials and designs have made possible improved cases, meter switches, transformers, circuit breakers, and other rectifier protective devices.

Variations in rectifier types such as small oil immersed units have resulted in better distribution factors and less interference by means of distributed ground bed systems. Rectifiers with multiple outputs have been used in some applications with good results at a lower cost.

Control of rectifier output has made many advances and will make many more in the near future. Present controls such as link bars and tap switches have been supplemented by constant current and special automatic current control rectifiers. Maintenance and inspection of the rectifiers has been greatly reduced and will be reduced even more in the future. Two controls of the future toward which much progress has been made are silicon power transistors and rectifiers which are controlled to a reference potential. 5.2.3

Introduction

AS THE TECHNOLOGY of design and manufacturing advance, all industry must also advance in order to receive the full benefit of these improvements. The cathodic protection rectifier industry has advanced along with technology in producing a better rectifier for the dollar. As in most industries, the consumers are interested in obtaining cathodic protection for the least overall cost. In order to accomplish this goal, the consumer must analyze his costs correctly considering all costs including overhead, maintenance, inspection, and service life. In many cases, the first cost of an installation which is more expensive will be cheaper in the long run due to a lower operating expense. The most economical rectifier to use is one which results in the least overall cost of the system. Often a few dollars spent initially will have many more dollars by means of a few cents at a time over a long period of time.

Such items as number of rectifiers, ground bed design, aged rectifier stack replacement, and rectifier quality level require economic studies to determine the final solution. The same is true of rectifier manufacture. The most economical rectifier design is the one which results in the best rectifier for the least money. Many of the new developments in cathodic protection rectifiers are aimed at this most-for-the-money goal.

One recent development is a movement toward standardization of rectifiers. This standardization covers many phases such as case sizes, DC voltage ratings, DC current ratings, input voltage ratings, and mass production type units. Referring to Chart No. 1 in Figure 1, efficiency vs. voltage, it can be seen that because 28 volts is the highest rating readily available in a selenium plate, a curve 1-28 volts is shown for a single plate. The 29-56 curve represents two plates in series and 57-84 represents three plates in series. The operating efficiency of a rectifier is determined by:

1. The number of plates in series
2. The voltage at which it is operated

As can be seen on the chart, if the operating voltage lies between 1-28 volts, a single plate or a 28 volt rectifier will be the most efficient. If the operating voltage lies between 29-56, two plates in series must be used and a 56 volt rectifier will be required. A 40 volt rectifier will still require two plates in series and its efficiency will lie along the 29-56 volt curve. A 56 volt rectifier operating at 40 volts will operate at the same efficiency as a 40 volt rectifier operating at 40 volts. This same reasoning can be applied to 3 plates in series or 57-84 volts.

Chart No. 2 in Figure 1 expresses the same reasoning applied to three-phase rectifiers. Three phase steps are 1-44, 45-88, 89-132, etc. Three phase efficiencies are usually considerably higher.

On Charts 1 and 2, within any of the voltage ranges expressed above, i.e., 1-28, 28-56, 57-84, for single phase, 1-44, 45-88, 89-132 for three phase, and the same current rating, there is very little price difference, and it may be well to consider buying the highest rating in the range. As demonstrated above, no loss in efficiency occurs when operating at a lower voltage than rated unless the operating voltage is 28 volts below rated for single phase, or 44 volts below for three phase.

On both Charts 1 and 2, silicon curves are shown. Silicon cells do not require a series hookup to increase the voltage rating, and therefore have one smooth curve of efficiency vs. voltage. As the voltage rating increases, silicon increases its superiority in efficiency as compared to selenium.

Chart 3 of Figure 1 shows that efficiency increases as current drops to approximately 50 percent of rated current. Below approximately 20 percent of rated current, efficiency drops off rapidly. This shows that conservatively rating stacks on current not only increases life due to less overheating, but also increases efficiency.

Purchasing a rectifier of slightly over the desired current rating costs very little and will increase efficiency and life. The greatest influence on the cost of a rectifier is the number of selenium plates in the unit. Increasing the rating of a rectifier a small amount will affect the price very little if the number of selenium plates remains unchanged. If the standard ratings for rectifiers are chosen to obtain a maximum utilization of the selenium plates, purchasing a standard rectifier and using it somewhat below rating will involve little more manufacturing material costs. This slight increase in manufacturing material costs is usually more than offset by the decrease in manufacturing labor cost made possible by using standard ratings. Standarization results in better utilization of materials and labor in designing and manufacturing rectifiers. It also makes servicing and maintenance less costly and easier for the consumer when less different ratings are in operation. These gains are made with no loss of efficiency due to a greater rating than the minimum needed to do the job.

Another trend today which is closely allied with standard rated rectifiers is the move in many applications toward more smaller rectifiers instead of one large one. Figure 2 shows how less current is in the crosshatched area of wasted current when a greater number of rectifiers are used. Another reason for these smaller units is that in congested areas, the interference problems are far fewer and much easier to solve with many small rectifiers. Also, with the increase in availability of power, now many rectifiers can be used where a few years ago power was available at only one place in the system. Special small rectifiers of high quality can be produced cheaply by using mass production techniques and offering only a limited number of ratings.

In some applications, more than one rectifier may be necessary to accomplish the cathodic protection. Examples of this

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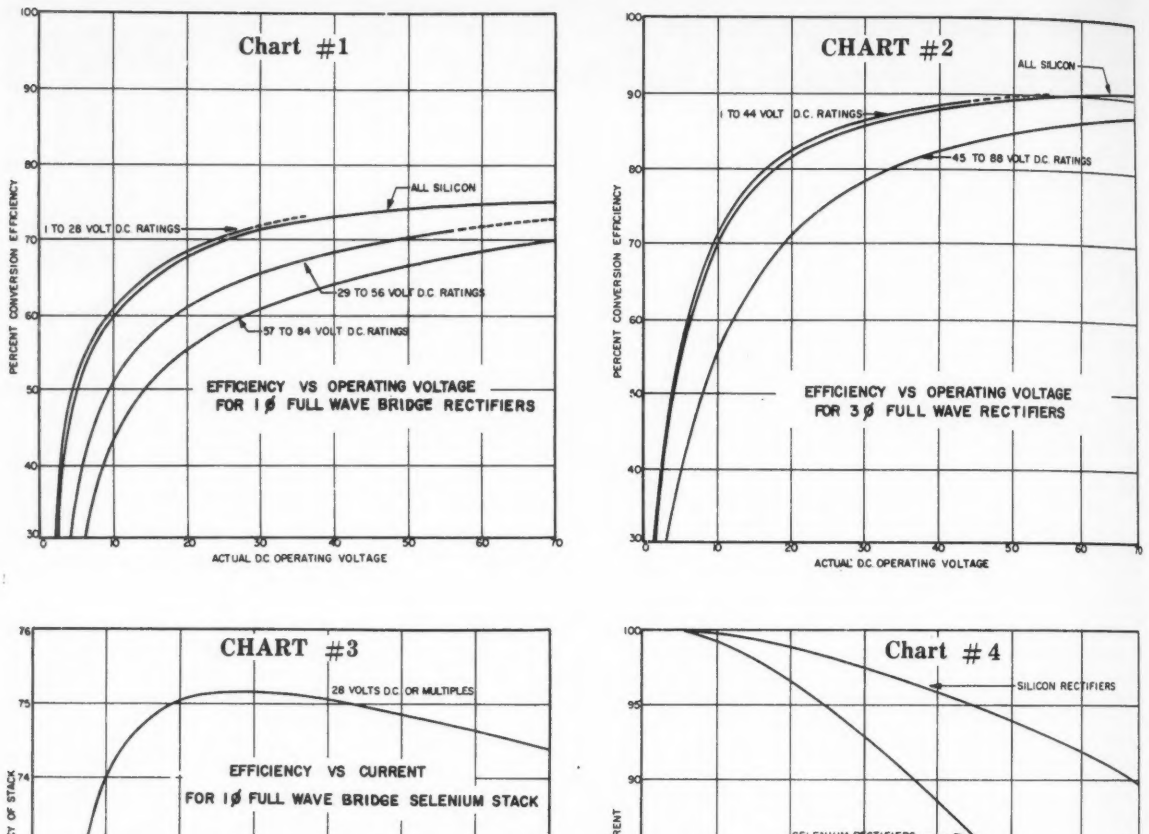
Chart #1
PERCENT CONVERSION EFFICIENCY
ALL SILICON
1 TO 28 VOLT D.C. RATINGS
29 TO 56 VOLT D.C. RATINGS
57 TO 84 VOLT D.C. RATINGS
EFFICIENCY VS OPERATING VOLTAGE
FOR 1 Ø FULL WAVE BRIDGE RECTIFIERS
ACTUAL DC OPERATING VOLTAGE
CHART #2
ALL SILICON
1 TO 44 VOLT D.C. RATINGS
45 TO 88 VOLT D.C. RATINGS
EFFICIENCY VS OPERATING VOLTAGE
FOR 3 Ø FULL WAVE RECTIFIERS
ACTUAL DC OPERATING VOLTAGE
CHART #3
PERCENT CONVERSION EFFICIENCY OF STACK
28 VOLTS D.C. OR MULTIPLES
EFFICIENCY VS CURRENT
FOR 1 Ø FULL WAVE BRIDGE SELENIUM STACK
20 VOLTS D.C. OR MULTIPLES
16 VOLTS D.C. OR MULTIPLES
PERCENT OF RATED STACK CURRENT
Chart #4
PERCENT OF RATED CURRENT
SILICON RECTIFIERS
SELENIUM RECTIFIERS
CURRENT DERATING CHART
AIR AMBIENT TEMPERATURE °F
AIR AMBIENT TEMPERATURE °C

Figure 1—Operating efficiencies of rectifiers.

application are oil heater-treaters, water tanks, and chemical process tanks. For such applications a multiple output rectifier is much cheaper than several separate rectifiers. Figure 3 shows two such types of rectifier circuits. The left circuit is a transformer with 2 secondaries and 2 stacks. This application is used where large currents (about 10 amps or more) are required. It is more efficient than separate rectifiers because of the single transformer but is more expensive than the right circuit. The right circuit has the lowest initial cost. The highest voltage output is taken from the left output and is adjusted by taps as with a standard rectifier. The other output is taken from the right output and is reduced below that of the left output by the rheostat (R). Since the rheostat is a high power loss element, this circuit is less efficient than a circuit without a rheostat. For other than fairly small currents, the rheostat becomes expensive and this circuit is not practical.

A component which represents a considerable part of the cost of a rectifier is the transformer. There are three generally accepted classifications of transformers which are:

Class A—105 C
Class B—130 C
Class H—180 C

The difference between these classes is the operating temperature. Each class must be built from materials within the class in order to operate with long life at this temperature. Table 1 is a comparison of the cost of transformers. A year ago, Class B transformers cost somewhat more than Class A, so they were not widely used. Within the last year, enamel coated Class B square and rectangular magnet wire was developed and the price of all enamel coated Class B wire was reduced from 10 percent over Class A down to the same price as Class A magnet wire. Table 1 shows the economic results of these developments. Today Class B transformers are the most economical to build and also result in a smaller, lighter rectifier.

In order to protect the meters in a rectifier from surges which will ruin the meter, most consumers must have a meter switch of some sort in the rectifier.

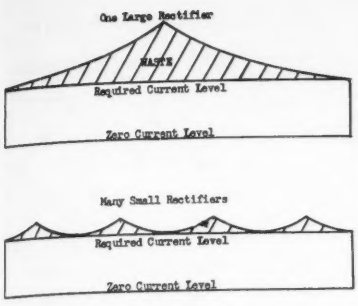

Figure 2—Rectifer utilization curves.

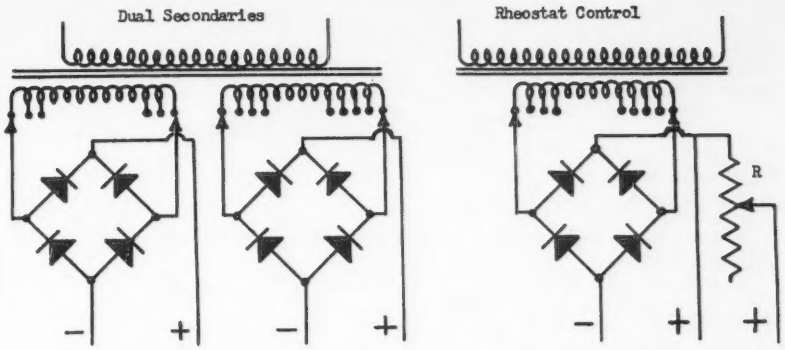

Figure 3—Multiple output rectifiers.

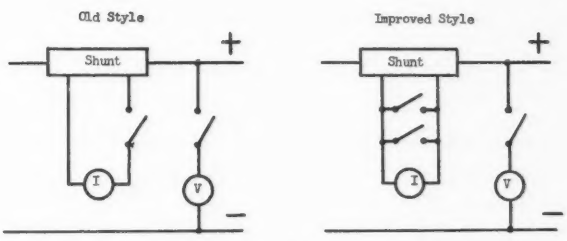

Figure 4—Meter switches.

These devices are a source of trouble in most cases.

Figure 4 shows a standard meter switch circuit on the left. Both switches are open when switch is not thrown. The voltmeter has a built-in high resistance and contact resistance does not affect its reading. The ammeter, however, is very sensitive to any resistance in the circuit. When the contact resistance of the switch varies, the meter reading varies. For this reason, meter switches are not desirable.

One method which helps to alleviate this problem is to throw the switch several times, taking a reading each time until 4 or 5 readings in a row are alike. The right circuit of Figure 4 will avoid this problem. In this circuit, the voltmeter switch is open and the ammeter switches are closed when the switches are not thrown. This results in the voltmeter not reading due to an open circuit and the ammeter not reading or reading only a very slight amount due to the switches shorting the meter. When the switches are thrown, both meters read. Note that at that time, there are no switch contacts in the ammeter circuit to cause variations in the reading. In the actual circuit, all the switches shown are in one housing with a single lever. This circuit allows a meter switch to be used to avoid ruined meters without the nuisance of corroded meter switches varying the ammeter reading.

Another development trend is toward more accessible rectifier cases. Figure 5 shows an example of one such case. This development results in easier maintenance and servicing.

Rectifier filters have been used much more in the last year or two. They result in practically no communications interference and increase the conversion efficiency of the single phase rectifiers about 10 percent. Three phase rectifiers have such low ripple content that filters do little to reduce communications interference or increase efficiency.

The last year has brought a great increase in the use of lightning arrestors. They are of great value on any rectifier and especially on the sensitive silicon rectifiers. The high voltage lightning arrestor for the input side or the output side of a high voltage rectifier is very successful due to great improvements in arrestors in the last few years. Most cathodic protection rectifiers, however, have low voltage outputs. To date, a good low voltage lightning arrestor is not available, but it will have application in cathodic protection rectifiers if ever successful. Inert gas type low voltage arrestors seem the best available now.

Constant Current Controlled Rectifiers

A really important development in cathodic protection rectifiers is the design and manufacture of constant current controlled rectifiers. Figure 6 shows the DC regulation curves for a standard voltage tapped rectifier and a constant current rectifier. On the standard voltage tapped rectifier, the numbered curves represent the output of the rectifier on each voltage tap adjustment. The resistance of any ground bed is represented by a straight line from the origin.

If the standard rectifier in the left diagram is set on adjustment No. 5, and the ground bed resistance is represented by line A, the current will be of the value from the left axis to the intersection C. Likewise, if the ground bed resistance increases to line B, then the current is reduced to the value from the left axis to the intersection D. Therefore, when the ground bed resistance varies, the output voltage remains practically unchanged, but the output current varies considerably.

In the right diagram of Figure 6, the constant current curves are shaped quite differently. If the constant current rectifier is set on adjustment No. 14 and the ground bed resistance is represented by line E, the current will be of the value from the left axis to the intersection G. If the ground bed resistance increases to line F, then the current is the value from the left axis to the intersection H. In this diagram, when the ground bed resistance varies, the output voltage varies considerably but the output current remains practically unchanged. To accomplish this effect, only the bottom two-thirds of the voltage range of the rectifier can be used. Under short circuit conditions when the resistance line is almost horizontal, the current increases slightly but does not harm the rectifier.

The higher voltage rectifying elements necessary to allow for the unused upper one-third of the voltage range and the excellent short-circuit characteristics of this type rectifier make it a perfect application for silicon stacks. In practice, curves numbered 10 through 15 are not the only adjustments available. The output current is varied by means of many closely spaced curves. This is possible because a very small rheostat with many steps is used to vary the control current from the small control rectifier to the saturable control reactor.

Figure 7 shows the circuits used to obtain the curves of Figure 6. The standard voltage tapped rectifier on the left is varied in current by moving the voltage taps to various positions on the transformer. The constant current recti-

TABLE 1—Transformer Costs

	Class A		Old Class B		New Class B	
Copper Wire	35# x 0.60 =	$21.00	25# x 0.80 =	$20.00	25# x 0.60 =	$15.00
Core Iron	100# x 0.20 =	20.00	90# x 0.20 =	18.00	90# x 0.20 =	18.00
Insulation	3# x 0.40 =	1.20	3# x 2.50 =	7.50	3# x 2.50 =	7.50
Totals	138#	$42.20	118#	$45.50	118#	$40.50

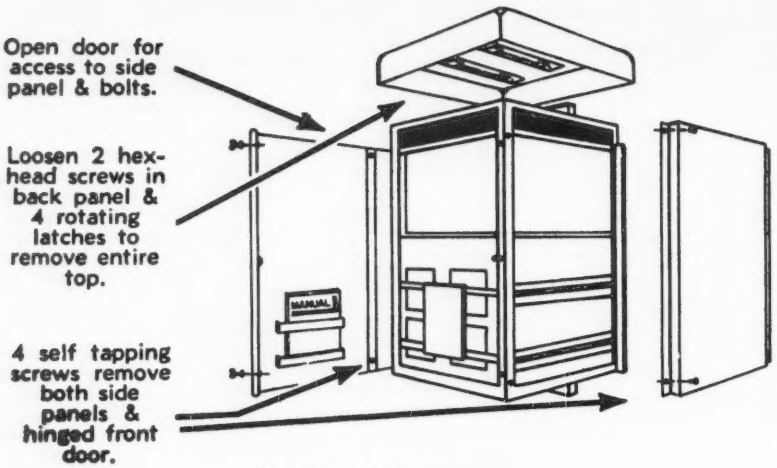
Open door for access to side panel & bolts.
Loosen 2 hex-head screws in back panel & 4 rotating latches to remove entire top.
4 self tapping screws remove both side panels & hinged front door.
MANUAL

Figure 5—A new type rectifier case.

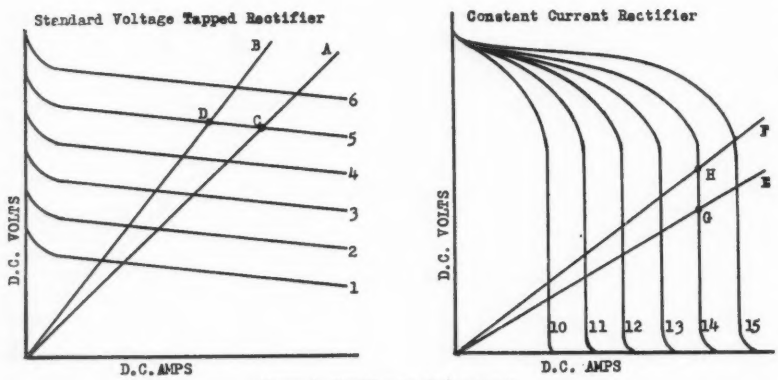

Figure 6—Rectifier regulation curves.

fier on the right is varied in current by adjusting a small rheostat which varies the control current from the small control rectifier to a winding on the saturable control reactor (L). The DC output also passes through windings on the saturable control reactor to obtain the proper shape on the curves of Figure 6. The reactor is a series impedance in the circuit and is automatically varied by the circuitry to obtain the desired current output. Since there are no moving parts or contacts other than the small control rheostat, these rectifiers are easily adjusted and extremely reliable.

Thus far very few constant current controlled rectifiers have been used although offered by many suppliers. The reason for this seems to be that the price of these rectifiers is about 50 percent greater than a standard rectifier of the same power. If the consumer would analyze the true cost of inspection, adjustment, and maintenance, the savings possible with this type of rectifier would be readily seen.

In addition to the two types of rectifiers just discussed, many others can be designed that have special types of desired DC output regulation curves.

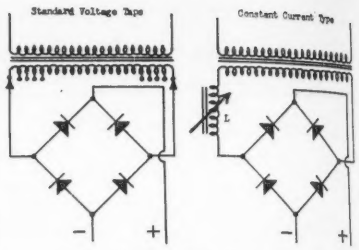

Figure 7—Controlled rectifier circuits.

Another development in the special controlled rectifier line is the recent marketing of a silicon power triode. These triodes are very similar to transistors and can handle fairly large amounts of power with very little control power necessary to obtain the desired output. They are at present very expensive as were silicon diodes when they were first marketed. The future use of these triodes is sure to be increasing greatly in the next few years. These triodes can be used to advantage in the development of reference potential controlled rectifiers which at present are economically beyond reach.

Another important development which is in progress and which has been in progress for several years is the manufacture of high voltage rectifying elements. Selenium and silicon rectifying elements have been increasing in maximum available voltage ever since their development. Charts 1 and 2 of Figure 1 show how higher voltage elements increase efficiency. The dotted extensions on the selenium curves can be used as higher voltage selenium plates are available. Silicon diodes are presently made in voltages which are high enough to use in cathodic protection rectifiers for most applications.

Figure 8 shows the voltage derating necessary for selenium plates. A few years ago, the highest voltage selenium plate available was 33 volts RMS which could be used to build a 20 volt DC single phase full-wave bridge rectifier with only one plate in series. About two years ago, 45 volt RMS plates were marketed which raised the single phase full-wave bridge to 28 volts DC output. Recently some manufacturers of selenium plates made available 52 volt RMS plates which will raise the single phase full-wave bridge to about 34 volts DC output. The 52 volt RMS selenium plates are

TABLE 2—Comparison of Single Phase Rectifiers

Characteristic	1Ø F.W. Center Tap	1Ø F.W. Bridge
New Efficiency	70%	64%
Aged Efficiency	62%	54%
Cost of Stack Replacement	50%	100%
Communications Interference (% Ripple)	47%	47%

ADVANTAGES OF 1Ø F.W. CENTER TAP CIRCUIT

Lower initial cost (up to 15 percent savings).
Higher new efficiency (up to 10 percent).
Higher aged efficiency (up to 10 percent).
Only one-half stack replacement cost.
Smaller cases in selenium and oil-immersed types.

TABLE 3—Comparison of Three Phase Rectifiers

Characteristic	3Ø Wye	3Ø F.W. Bridge	1Ø F.W. Bridge
New Efficiency	88%	83%	69%
Aged Efficiency	80%	70%	60%
Cost of Stack Replacement	56%	100%	100%
Communications Interference (% Ripple)	17%	4%	47%

ADVANTAGES OF 3Ø WYE CIRCUIT

Lower initial cost (up to 15 percent savings).
Higher new efficiency (up to 15 percent).
Higher aged efficiency (up to 15 percent).
About one-half stack replacement cost.
Smaller cases in selenium and oil-immersed types.
One-thired communications interference of 1Ø F.W. Bridge.
Simplified circuits for easier servicing.

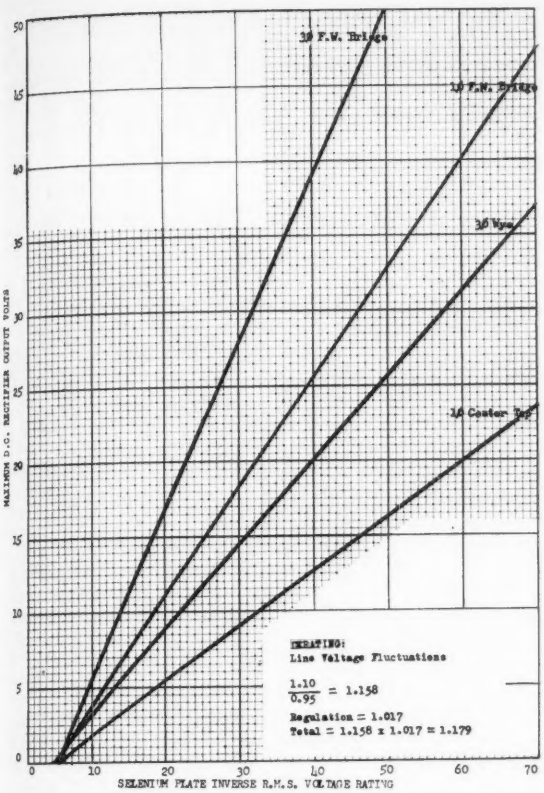
MAXIMUM D.C. RECTIFIER OUTPUT VOLTS
SELENIUM PLATE INVERSE R.M.S. VOLTAGE RATING
RATING:
Line Voltage Fluctuations
1.10/0.95 = 1.158
Regulation = 1.017
Total = 1.158 x 1.017 = 1.179

Figure 8—Maximum rectifier output volts vs selenium plate inverse RMS rating. Formulas are as follows: 1 phase FW Br Vac = 1.179 (1.15 Vdc 5); 3 phase FW Br Vac = 1.179 (0.745 Vdc 5); 1 phase Cen Tap Vac = 1.179 (2.3 Vdc 5); 3 phase Wye Vac = 1.179 (1.49 Vdc 4.33).

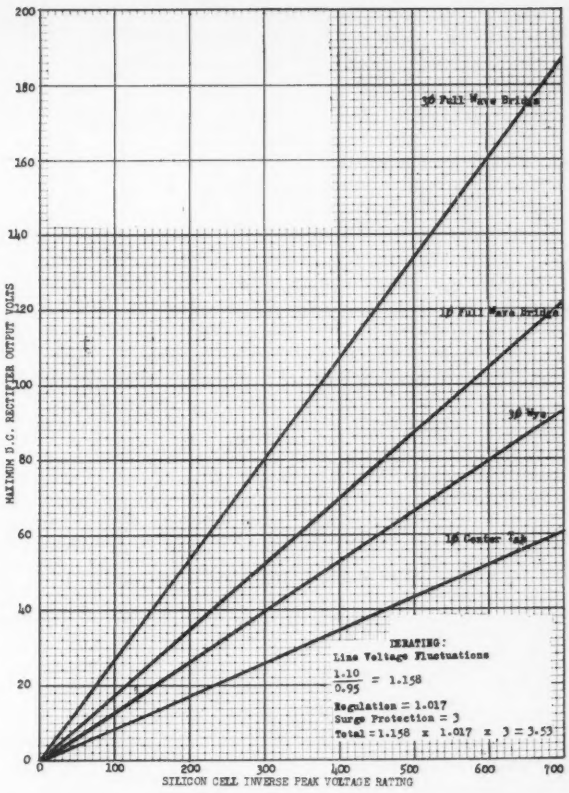
MAXIMUM D.C. RECTIFIER OUTPUT VOLTS
SILICON CELL INVERSE PEAK VOLTAGE RATING
RATING:
Line Voltage Fluctuations
1.10/0.95 = 1.158
Regulation = 1.017
Surge Protection = 3
Total = 1.158 x 1.017 x 3 = 3.53

Figure 9—Maximum DC rectifier output volts vs silicon cell inverse peak voltage rating. Formulas are as follows: 1 phase FW Br Vac = 3.53 (1.15 Vdc 3); 3 phase FW Br Vac = 3.53 (0.745 Vdc 3); 1 phase CT Vac = 3.53 (2.3 Vdc 3); 3 phase Wye Vac = 3.53 (1.49 Vdc 2.6).

still rather new and field experience is not complete. They also require considerable forward current derating at this voltage to avoid overheating the plate.

The reasons for the difference in the RMS selenium plate voltage rating and the DC output voltage obtainable from this plate are many. National Electrical Manufacturer's Association, Semiconductor Rectifier Section has set standards for cathodic protection rectifier units as follows:

(1) Rectifiers shall operate at 5 percent below nominal input voltage with aged selenium plates and deliver full rated voltage.

(2) Rectifiers shall operate at 10 percent over nominal input voltage without harmful effects to the selenium plates.

Also, the selenium plates are rated with RMS voltage ratings and rectifiers are rated with average values of voltage ratings. This difference requires a 15 percent increase of selenium plate RMS voltage rating over rectifier average DC voltage ratings. The voltage regulation of the transformer requires a small increase of selenium plate RMS voltage ratings over rectifier average DC voltage ratings. All these factors and the resulting formulas and plots are shown on Figure 8. These voltage derating factors are all very necessary as proven by field experience and reducing this derating will result in early selenium stack failure due to overvoltage.

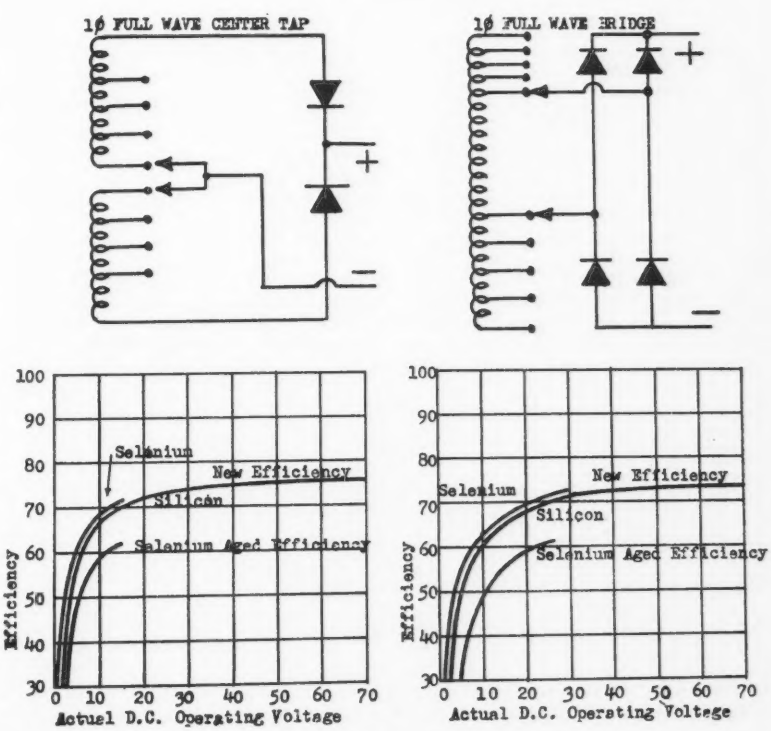

Figure 10—Single phase rectifiers.

Selenium plates are also available in high current density types from many manufacturers. These plates offer a somewhat less expensive rectifying element. Two distinct drawbacks are present. At present, these plates are available only up to 33 volts RMS ratings. These plates are of fairly recent development and tests indicate considerable variation in the performance.

Silicon diodes for cathodic protection require all the voltage deratings required by selenium plus two more. Since silicon diodes are rated by peak volts instead of RMS volts as are the selenium plates, an additional factor of the square root of two is necessary. Also, silicon is very sensitive to surges that are quite common in cathodic protection applications. Silicon diode manufacturers and field experience show that an additional factor of 3 is necessary in silicon voltage derating as compared with selenium. All these factors and the resulting formulas and plots are shown in Figure 9. Silicon diodes can be purchased with 600 volts peak ratings and the future diodes available will have even higher voltage ratings.

Silicon rectifiers have several advantages:

1. They are more efficient than selenium when more than one plate in series is necessary.
2. No aging loss in efficiency is present.
3. Initial cost is lower in high voltage, high current, high ambient temperature (see Chart 4 of Figure 1), or oil-immersed rectifiers.
4. Maintenance is easier due to simple stack configurations.
5. Silicon rectifiers are smaller and lighter.

The disadvantage of silicon rectifiers is that they are sensitive to overloads and surges. Lightning arrestors should always be used on both the input and output. High speed fuses should be used to protect the rectifier from accidental short circuits. Proper voltage and current deratings should be used to help absorb surges. As the protection problem for silicon is improved and increased production is realized, the future use of silicon will increase.

The development of high voltage selenium plates and silicon diodes has made possible another development in the cathodic protection rectifier industry. Single phase half-wave and three phase wye rectifier circuits have long been known to rectifier builders. These circuits are very practical when using high voltage elements such as vacuum tubes.

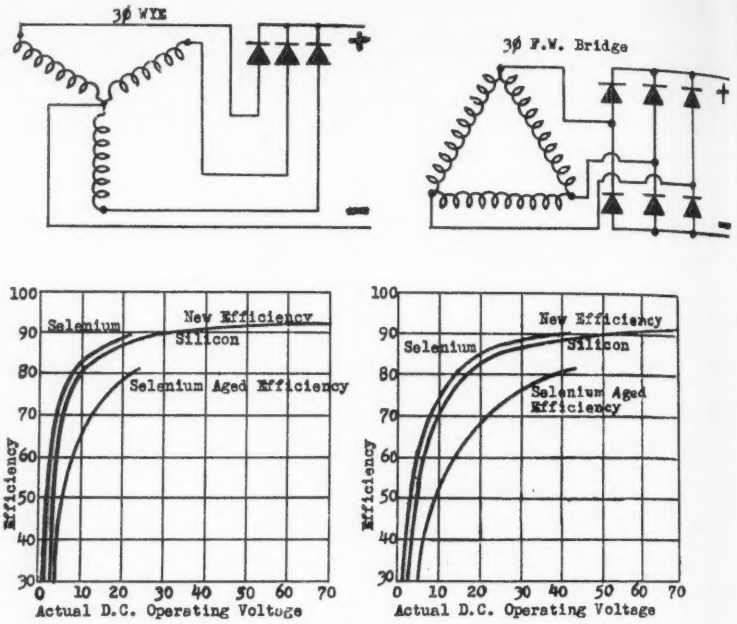

Figure 11—Three phase rectifiers.

Referring to Figure 8, it is seen that when only 26 volt RMS selenium plates were available, single phase center tap rectifiers were capable of only 7½ volts DC output and three phase wye rectifiers were capable of only 12 volts DC output. These voltages were too low for cathodic protection rectifier applications. Greater DC voltage ratings can be obtained by using more than one plate in series, but this is not a practical application since it will gain nothing over bridge type circuits. Now that 45 volts RMS selenium plates are available, the DC output voltages available from these new circuits are 14 and 22 volts DC output. Using 52 volts RMS selenium plates will give 17 and 26 volts DC output. These voltages are very much in the range of practical application for cathodic protection rectifiers. As higher voltage selenium plates are available in the future, these circuits will be even more in the usable voltage range. Silicon cells have far greater inverse voltage ratings than selenium, and can be used to manufacture cathodic protection rectifiers of almost any DC voltage rating desired.

Figures 9 and 10 with Tables 2 and 3 show the circuits, efficiency curves, and advantages of single phase center tap and three phase wye rectifiers. Note that in each case, the new circuits contain only half the number of rectifying elements as their comparable bridge circuit. This results in less power loss due to less elements to create heat. Aging effects and stack replacement costs are reduced to about one-half. With less material in the rectifiers, the initial cost is usually less. All these advantages are gained at the penalty of a reduced maximum DC output voltage as seen by the figures. These circuits do not increase the current in any rectifying element so that quality and long life are not reduced.

In conclusion, these developments in cathodic protection rectifiers are now and will continue to be beneficial to the cathodic protection industry. Many more developments are now in the making for the future.

Any discussion of this article not published above will appear in the December, 1960 issue.

Boiler Model Tests of Materials For Steam Generators In Pressurized Water Reactor Plants*

By E. HOWELLS, T. A. McNARY and D. E. WHITE

Abstract

An evaluation was made of various materials on the secondary side of boiler models built and operated in simulation of a full scale unit in a pressurized water nuclear power plant. Materials tested included stainless steel, carbon steel, Croloy 2¼, Croloy 16-1, nickel, Inconel, and Monel. Considerable attention was given to problems involving stress corrosion cracking, particularly of Type 347 stainless steel tubing. Other topics discussed include control of dissolved oxygen concentration, pitting corrosion, and location of tubing areas most susceptible to corrosion. 7.6.4

Introduction

IN A PRESSURIZED water nuclear power plant the steam generator serves as the link between the primary and secondary systems. The tubing in the steam generator is unique in that it is exposed to both the primary and secondary water. For this reason material selection must be made with concern for suitability in both environments.

On the primary side the tube material must be resistant to general corrosion in high purity water. Also it must not introduce a corrosion product into the primary system that will produce a biological hazard upon activation in the nuclear core.

On the secondary side the tube material must resist both general and localized forms of corrosion in a boiler water type of environment.

This paper is concerned with the evaluation of various materials on the secondary side of boiler models built and operated in simulation of a full scale unit in a pressurized water nuclear power plant.

The screening of materials to determine their basic resistance to chloride stress-corrosion cracking was carried out in a separate but associated program by means of tilting autoclave tests using U-bend type specimens. In that program it was determined that carbon steel (with or without chromium additions), Croloy 16-1, Inconel, Monel, and commercial nickel were not subject to chloride stress-corrosion at least as compared to Type 347 stainless steel. These materials were selected for boiler model tests as reported herein.

The need for boiler model tests is similar to the need for pilot plant operation of any new development before full scale operation is attempted. Autoclave and loop corrosion tests are very suitable for screening materials and determining quantitative corrosion data, but there are a number of environmental conditions that do not lend themselves well to simulation in autoclaves.

Foremost among conditions that can best be evaluated in a small heat exchanger is that of heat throughput. The boiler models used in this program were designed to provide corrosion information on various tube alloys used for heat transfer surfaces in the presence of steam blanketing, alternate wetting and drying, crevice, and stressed crevice conditions. From these tests, information has been gained on the stress-corrosion, general corrosion, crevice corrosion, and pitting corrosion characteristics of the test alloys under relatively severe conditions.

Test Apparatus

The test specimens were heat exchanger models approximately 18 inches high and six inches in diameter. Each unit consisted of a primary head, a horizontal tube sheet containing six active U-bend tubes with tube support plates, and a secondary shell. As shown in Table 1 there were three units each of Inconel, Monel, nickel, Croloy 2¼; one of Croloy 16-1; and two of Type 347 austenitic stainless steel. One of the Type 347 units had a SA-105 carbon steel tube sheet. The materials of construction were of commercial quality with shop-type fabrication procedures being used wherever possible.

Each of the ½ inch OD by 0.050 inch wall tubes were bent and, with the exception of the Type 347, were installed without heat treatment. The Type 347 tubes were resistance annealed at 1850 F for 35 seconds, followed by water quenching. All tubes were given a dye penetrant test for any indications of cracks, scratches and pits. Tubes showing defects were rejected as unsuitable for tube specimens.

The order of construction was to roll the tubes into the tube sheet, make the seal weld between the tube and tube sheet, weld the secondary shell to the tube sheet, leak check the seal welds and finally weld the primary shell to the tube sheet to complete the unit. Tube support plates were added to create a plate to tube crevice such as is found in a full scale unit. Figure 1 shows the appearance of the components before assembly.

A retractable expander was used to expand the tubes 0.020 inch beyond contact with the tube sheet, as measured by the increase in the ID of the tube. The diameter of the hole through the tube sheet increased by about 0.001 inch. After final assembly of the heat exchangers, the secondary shells were pressurized with helium gas and the welds were checked for leaks with a mass spectrometer. The Croloy 2¼ units and the Croloy 16-1 unit were stress relieved in an inert gas atmosphere at 1350 F and 1150 F respectively; no heat treatment was given to the remaining units. The heat exchangers were then installed in the test loop.

Figure 2 is a schematic diagram of the test loop. The primary circuit was essentially a rectangular loop made with stainless steel piping. Water was circulated around the system with a canned rotor pump. The instrumentation was such that the pressure and temperatures of the system were automatically controlled. The flow of primary water through the heat exchangers was controlled with valves on the inlet and out-

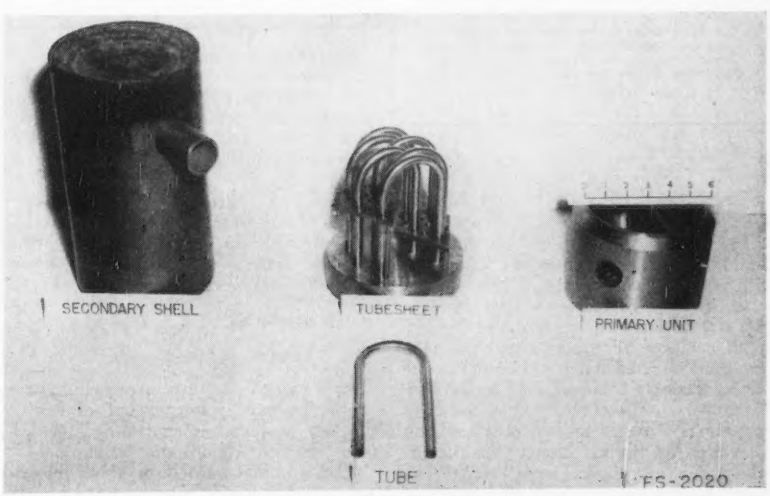

Figure 1—Components of heat exchanger model.

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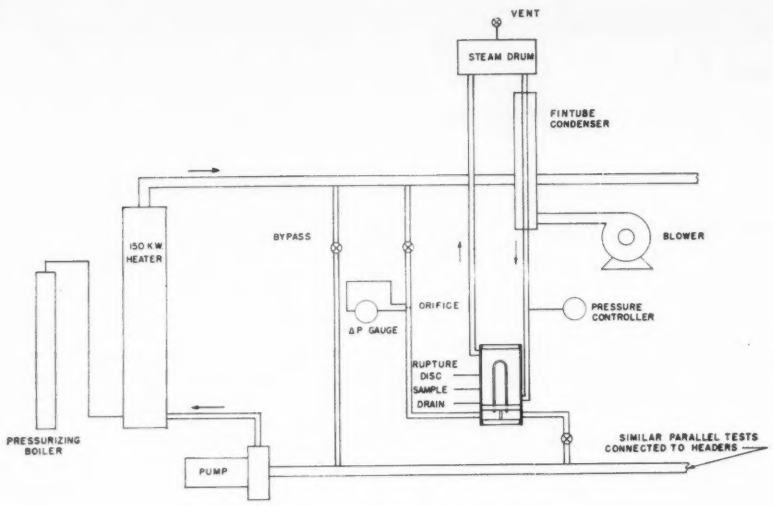

Figure 2—Schematic diagram of test loop.

McNary

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Howells

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White

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let sides, and measured by means of a calibrated orifice plate located in the inlet line.

The secondary system, with the exception of the heat exchangers, was made with carbon steel piping. The steam-water mixture flowed up a riser by natural circulation to a steam drum located at the top of the loop about 14 feet above the heat exchanger. The flow continued through a finned tube located in the downcomer and returned to the heat exchanger. The secondary pressure was controlled by the air blown past the fin tubes. Thermocouples were located at many points around both the primary and secondary systems.

Sampling stations were provided so that water samples could be taken from almost any part of the test loop. This included the primary system, the secondary riser and downcomer, the heat exchanger, and the steam drum.

Procedure

Before any water was allowed to circulate through the heat exchangers, the primary system was allowed to reach the following conditions:

Pressure	2000 psig
Temperature	600 F

There was no chemical treatment given to the primary water except to run it through a deionizer and deaerator before pumping it into the system.

The nominal secondary water conditions during steady state operation were as follows:

pH	10.9 ± 0.3 (adjusted with $NaOH$)
Cl^-	500 ± 50 ppm (added as synthetic sea water)
$PO_4 \equiv$	250 ± 50 ppm (Na_2HPO_4)
Dissolved O_2	0.2—0.5 ppm (by aeration)
Temperature	480-490 F
Pressure	600 psig

Reagent grade chemicals were used at all times to maintain the water chemistry. The synthetic sea water was prepared according to ASTM specification D1142-52.

The primary water circulating through the U-bend tubes transferred heat to the secondary system with a flux of 40,000-60,000 Btu/hr-sq. ft. of tubing based on the tube ID. After 48, 192 and 336 hours of operation, the heat exchangers were laid up dry for a period of eight hours. The secondary system was purged with water-saturated air during the lay-up. After 96, 240 and 424 hours of operation, 60-90 percent of the U-bend tube heat transfer area was exposed to the vapor phase for a one hour period; and after 144, 288 and 472 hours of operation, the heat exchangers were laid up wet for a period of eight hours. During this latter operation, the secondary system was completely filled with treated boiler water. Air was injected near the bottom of the exchanger and allowed to bubble up through the system to escape out the top vent.

At the end of the test period, slightly over 500 hours, the secondary system was quickly emptied by venting steam through the top vent. The boiler water chemicals deposited on the heat transfer surfaces as a result of permitting the primary water to circulate during the boil dry. The primary water flow was then stopped and the test loop was allowed to cool to room temperature.

The heat exchangers were cut from the loop and given a helium leak test. Only one boiler out of the 15 tested showed indications of an extremely small leak which was never definitely located. They were then given a very complete metallurgical examination.

During the testing of each unit, numerous water samples were analyzed for pH, Cl^-, $PO_4 \equiv$ and dissolved oxygen. Adjustments of the defined chemical concentrations were made with concentrated chemical solutions, or, in the case of high values, by blowdowns. The dissolved oxygen was controlled by aerating boiler water withdrawn from the secondary system and pumping it back into the same system.

Metallurgical Examination of Tested Units

The first step in the evaluation of tested heat exchanger models was visual inspection of all the secondary surfaces after removal of the primary and secondary shells. The U-tubes were cut off at a level about one inch above the tube sheet secondary surface and the indi-

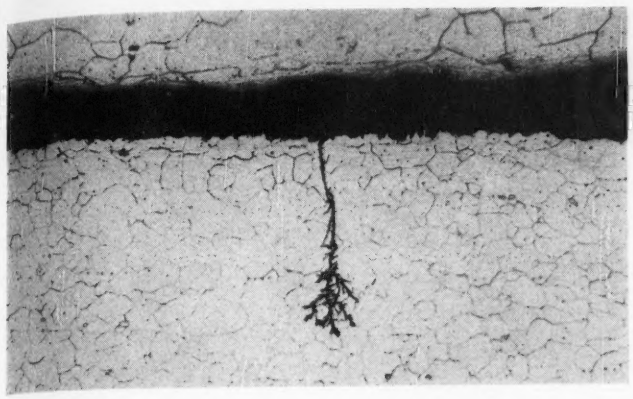

Figure 3—Representative stress-corrosion crack in Type 347 tube within stainless steel tube sheet. Electrolytic 70 percent nitric acid, approximately 400X.

TABLE 1—Construction Material

Model No.	Tube Material	Tube Sheet Material	Shell and Head Material
U-1	Type 347 Stainless Steel	Type 347 SS	Type 347 SS
U-2	Type 347 SS	SA-105 Carbon Steel	Type 347 SS
U-5, U-6, U-7	Croloy 2¼	Croloy 2¼	Croloy 2¼
U-8	Croloy 16-1	Croloy 16-1	Croloy 16-1
U-9, U-19, U-20	Inconel	Inconel	Inconel
U-10, U-11, U-12	Monel	Monel	Monel
U-15, U-16, U-17	Nickel	Nickel	Nickel

vidual tube to tube sheet junctions were cut out of the tube sheet. After cutting off the seal welds of the junctions, two longitudinal cuts were made through the tube sheet material on opposite sides of the junction, providing two tube sheet sections which could be separated from the tube without marring the crevice surfaces.

After completion of this disassembly, all parts of the boilers were examined at 22 diameters magnification before descaling to determine the amount and character of deposits and corrosion products at various locations, with particular attention being paid to the crevices of the tube to tube sheet junctions. All components were then descaled, and the U-tubes were inspected by the "Zyglo Pentrex" fluorescent penetrant technique as an aid in locating stress-corrosion cracks. All sections of the boilers were examined at 30 diameters magnification after descaling. Observations of surface conditions, corrosion, cracking, etc. were recorded. Metallographic sections through pertinent locations were prepared and examined to determine the type and extent of general and pitting corrosion and stress-corrosion cracking.

Results

General

After completion of testing, the secondary surfaces of all boilers were covered with adherent powdery deposits up to 0.025 inch thick. Markings were usually evident in the deposits on the U-tubes of the low water level operation periods. In general, there were powdery deposits on the crevice surfaces of the tube to tube sheet junctions similar to those on the exposed tubing. These deposits were only in the area immediately below the secondary face of the tube sheet. Evidence of oxidation of these surfaces extended further into the crevices in all cases.

Corrosion of the crevice surfaces was generally limited to those regions which had been covered by deposits. Corrosion of open secondary surfaces of the U-tubes was randomly distributed with only the support plate contact region showing consistently more advanced attack. The maximum depth of attack on a given tube was not necessarily at a support plate crevice area, but these zones at least displayed a greater propensity to pitting. Stress-corrosion cracking was observed only in the two units containing austenitic stainless steel tubing.

Stainless Steel

All Stainless Steel Boiler Model. A series of very small stress-corrosion cracks occurred in the crevice surfaces of all twelve tube to tube sheet junctions and in three of the twelve tube support plate crevices (see Figure 3). All cracking in the tubes was predominantly circumferential while that in the tube sheet was exclusively longitudinal. The cracking in the crevice surfaces of the tube to tube sheet junctions was limited to the area within ¼ inch of the secondary face of the tube sheet. All cracking was predominantly transgranular, penetrating a maximum of 8 mils into the tube sheet and 6 mils into the tubes.

Metal loss due to general corrosion was negligible on all open secondary surfaces as well as crevice surfaces of tube to tube sheet junctions, these areas displaying, at worst, only light general "dulling" of the originally bright surface. However, five of the twelve tube surface areas under support plates were affected by slight surface roughening.

Duplex Boiler (Carbon Steel Tube Sheet). Stress-corrosion cracking occurred in the tubes of only two tube to tube sheet junctions of this model and, in both cases, the cracks were extremely small, oriented circumferentially and located within ¼ inch of the seal weld (see Figure 4). These cracks were transgranular and penetrated into the tube wall a maximum of 5 mils. The only areas where significant corrosion occurred on the stainless steel tubes were four of the twelve crevice regions under tube support plates where there was light surface roughening. At all other locations, the tube surfaces were only lightly dulled. The carbon steel tube sheet suffered severe pitting on both the secondary surface and the crevice surfaces of the tube to tube sheet junctions.

Croloy 2¼

All surfaces exposed to secondary water were affected by both general roughening and severe pitting, up to 15 mils deep (see Figure 5). The pitting was randomly distributed over the secondary surfaces but was of higher density in the crevice areas. Significant corrosion of the crevice surfaces of the tube to tube sheet junctions was limited to the region within ⅜ inch of the tube sheet secondary surface. All corrosion advanced in a gross manner, showing general progression without respect to the microstructure of the material.

Croloy 16-1

General and pitting corrosion of Croloy 16-1 was similar to that of Croloy 2¼ but was not as severe. All surfaces exposed to secondary water experienced general roughening and scattered small pits up to 5 mils in depth (see Figure 6). The crevice surfaces of the tube to tube sheet junctions displayed similar attack in the area within ¼ inch of the tube sheet secondary surface. Several of the tube surface areas beneath support plates displayed more severe atack than that on open tube surfaces.

Nickel

All open secondary surfaces of the nickel U-tubes were in excellent condition, displaying only very light general dulling. However, the surfaces of all U-tubes in the areas under support plates were pitted (up to 6 mils deep) and roughened (see Figure 7). Also, the crevice surfaces of the tube to tube sheet junctions were similarly corroded to a maximum depth of 4 mils in the area within ⅜ inch of the tube sheet secondary surface.

Inconel

All secondary surfaces of the U-tubes were in excellent condition, the only evidence of corrosion being a very light general dulling of the originally bright surface. Most of the tube surface regions under support plates experienced some incipient pitting or roughening. The crevice surfaces of the tube to tube sheet junctions displayed mild general attack

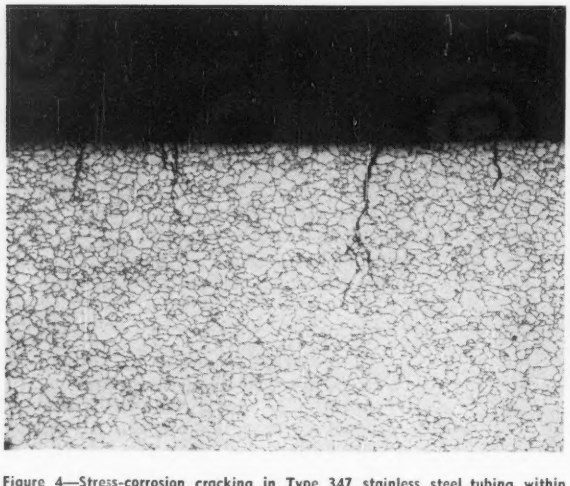

Figure 4—Stress-corrosion cracking in Type 347 stainless steel tubing within crevice formed with carbon steel tube sheet. Electrolytic 70 percent nitric acid, approximately 160X.

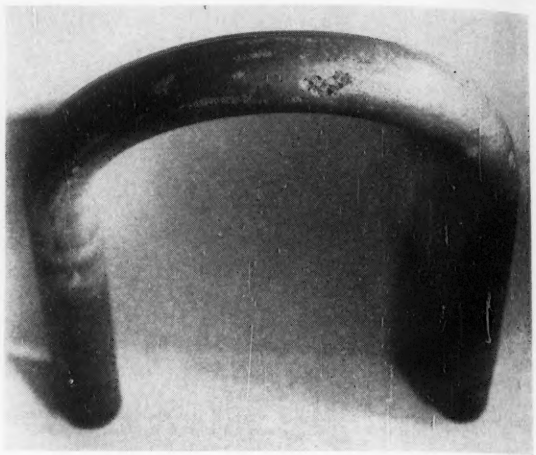

Figure 5—Typical extent of corrosion of Croloy 2¼ U-tubes.

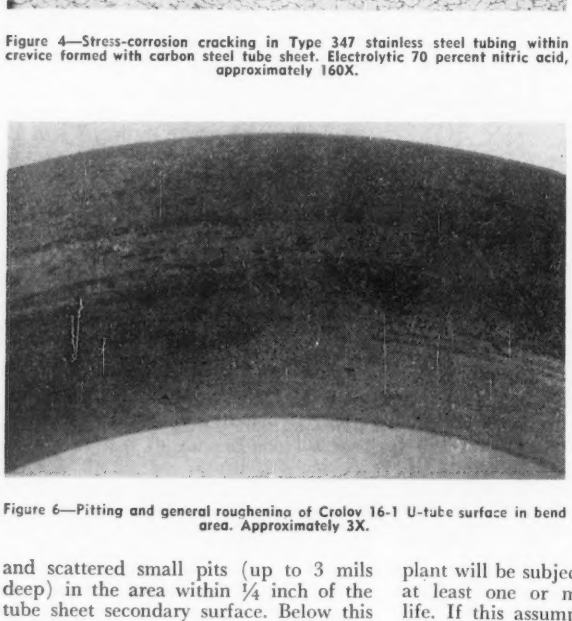

Figure 6—Pitting and general roughening of Croloy 16-1 U-tube surface in bend area. Approximately 3X.

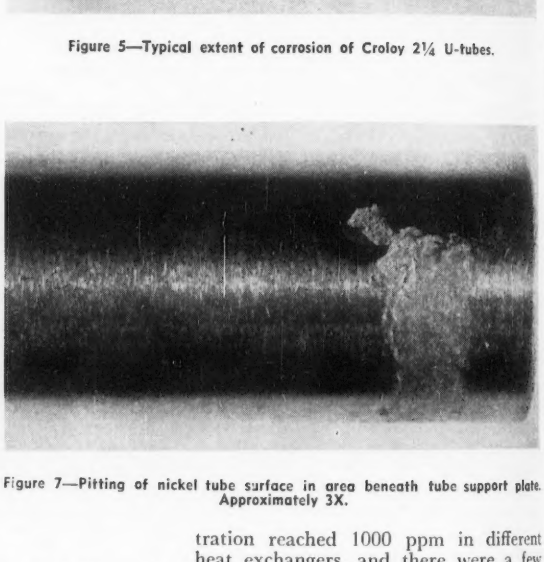

Figure 7—Pitting of nickel tube surface in area beneath tube support plate. Approximately 3X.

and scattered small pits (up to 3 mils deep) in the area within ¼ inch of the tube sheet secondary surface. Below this region the crevice surfaces were unattacked. As shown in Figure 8, the corrosion of Inconel crevice surfaces occurred as localized surface roughening rather than as clearly defined pitting. Metallographic examination revealed the attack to progress generally without respect to the microstructure of the material.

Monel

There was no significant corrosion on the Monel surfaces. All surfaces exposed to secondary water were slightly dulled by light general attack but in no instance was this corrosion severe enough to be termed pitting. The tube surface areas which formed crevices with either the tube support plates or the tube sheet displayed no evidence of preferential attack.

Discussion

The test conditions and chemical treatment of the secondary water to which the heat exchangers were subjected are considered to be relatively severe. The overall test conditions for this work were established from the basic thinking that a steam generator in a nuclear power plant will be subjected to such conditions at least one or more times during its life. If this assumption is correct, it becomes obvious that materials of construction must be those least susceptible to any type of corrosion, and especially chloride stress-corrosion.

During the fabrication of the heat exchanger models, every attempt was made to simulate actual fabrication procedures. Because these were test models, some deviations had to be made. For instance, in most cases no attempt was made to relieve stresses resulting from the fabricating procedure. The expansion of the tubes in the tube sheet and weld shrinkage caused residual stresses of an unknown magnitude which increases the susceptibility of some alloys to stress-corrosion cracking in a chloride bearing environment. If under such extreme conditions a material is found resistant to stress-corrosion cracking, it may be considered as suitable from a stress-corrosion standpoint for pressurized water reactor systems.

The control of the secondary water chemistry generally was good. On some occasions the Cl^- and $PO_4 \equiv$ concentrations were out of the limits already defined. On two occasions, the Cl^- concentration reached 1000 ppm in different heat exchangers, and there were a few times that the $PO_4 \equiv$ concentration was lower than that specified. In every instance, however, immediate steps were taken to make adjustments. At no time was the out-of-specification condition permitted to extend beyond four hours.

Considerable difficulty was experienced in controlling the dissolved oxygen concentration; there were a few times when the concentration reached 10 ppm. The high values were usually associated with the start-up of the heat exchanger models from the wet and dry lay-up operations. About 85 percent of the analyses were between 0.00 and 0.5 ppm and nearly all the remainder between 0.50 and 2.0 ppm. There were few times, however, when there was no oxygen detected.

The effects on test results by the excursions of the chemical concentrations from the test specifications are difficult to evaluate. One objective of this work was to provide specific test conditions that are considered to be severe enough to cause stress-corrosion cracking of a susceptible material. It is believed this objective was met, and that deviations of the secondary water chemistry did not compromise the validity of the tests.

The boiler models used in this pro-

gram were designed with statistical considerations in mind. The test data, however, indicate that this type of analysis was not necessary since chloride stress-corrosion cracking has been shown to be strongly "go-no-go" in nature. Observe that the control material (Type 347) displayed 100 percent cracking in the tube sheet crevices while the test alloys displayed 0 percent cracking.

The test was designed to crack Type 347 stainless steel for control purposes and as can be seen from the results, it was quite successful. Note that one of the Type 347 tubed units had a carbon steel tube sheet while the other was all stainless steel. This was done to determine if carbon steel would galvanically protect the stainless steel tubing in crevices. The results of these tests indicate that there is protection in this metallic combination, but that this protection is incomplete.

Cracks in the stainless steel tubing near the welds within the carbon steel tube sheet crevice were identified as stress-corrosion cracking (Figure 4). As a result of this test, it was concluded that the galvanic protection of carbon steel for stainless steel is not effective enough to be depended upon in full scale steam generators. All of the other test boilers were made of one material throughout in order to avoid galvanic effects since it was desired to test these materials for their basic resistance to chloride stress-corrosion cracking and not have the results disguised in any way.

The extensive cracking in the all stainless steel unit demonstrated that the crevices of a heat exchanger, particularly the stress crevices, are the most susceptible areas to stress-corrosion cracking. All the cracking in the tube sheet crevice was in a highly stressed area located about ¼ inch from the secondary tube sheet face. This area also represents the extent of water penetration into the all stainless crevice. On the other hand, examination of the tube surfaces from within the carbon steel tube sheet indicated that water penetration extended all the way to the seal welds on the primary face. The few cracks that were detected on the duplex unit were also in the end of the water penetration zone and coincidentally in the high stress area adjacent to the seal weld. In both the tube sheet and tube support plate crevices observations indicated that concentration of boiler salts (chlorides) was taking place. Thus, a complex relationship between solids concentration, high stress, and cracking is indicated in the crevice zones of these model heat exchangers.

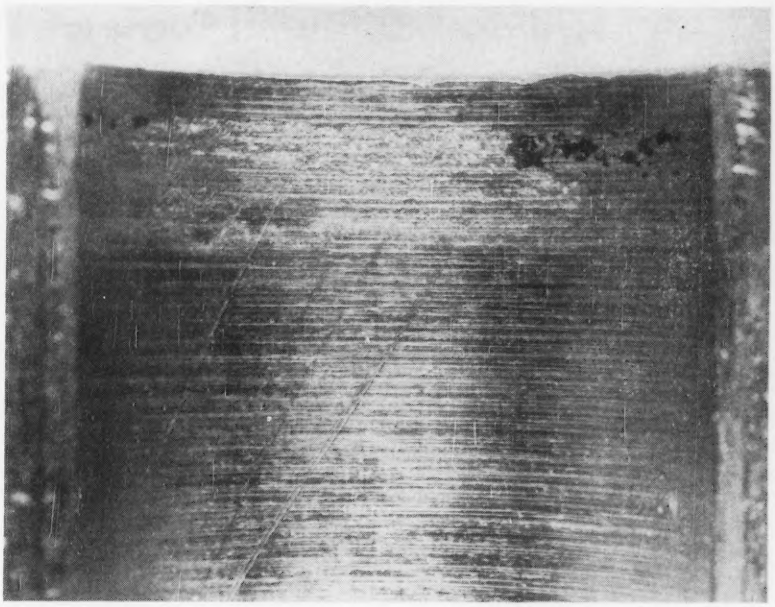

Figure 8—Typical corrosion of Inconel tube sheet crevice surface. Approximately 7X. Secondary surface is shown at top.

Metallographic examination revealed that the cracks ranged from 5 to 10 mils in depth in the Type 347 tubing. It is not known what percentage of the cracking depth was caused by or occurred during each of the various operational cycles. However, it is considered significant that no cracking was initiated in the test alloys, Inconel, Monel, nickel, Croloy 16-1 and Croloy 2¼ in the same 500 hours of cyclic operation. These results indicated that the test alloys would be suitable for steam generators from a chloride stress-corrosion standpoint.

Since cracking was not detected on any of the alloys except Type 347, general corrosion and pitting corrosion became the main criteria for comparing the alloys. The high-nickel alloys Monel, Inconel, and nickel were the most corrosion resistant, in some cases displaying some surface dulling and very small pits at the crevice openings. Croloy 16-1 ranked next since pitting up to 5 mils deep was observed on the bent portions of the tubes. It is possible that the plastic deformation in the bend area renders the material more susceptible to pitting in spite of the 1150 F stress relief. The general corrosion attack seen on the Croloy 16-1 confirmed the original impression that it is not as corrosion resistant as austenitic stainless steel or the high nickel alloys. However it is still to be considered a very promising steam generator tubing material. The low chromium steels such as the Croloy 2¼ are considered too sensitive to pitting for steam generator tubing.

Acknowledgments

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The authors acknowledge F. J. Pocock's special efforts in control of water chemistry in these tests.

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Any discussion of this article not published above will appear in the December, 1960 issue.

Hydrogen Diffusion Corrosion Problems In a Fluid Catalytic Cracker And Gas Plant*

By E. F. EHMKE*

Abstract

An account is given of corrosion problems in a fluid catalytic cracker and gas plant following a 19,000 hour run. Specific places where corrosion damage occurred and was examined include: (1) the carbon-moly steel reactor, (2) the regenerator, (3) catalyst lines, (4) the gas plant.

It was found that corrosion became a problem when coupled with erosion in cyclones or diffuser grids. Alloying could not be justified except on stressed parts.

Hydrogen blistering was discussed in detail. It was found that its occurrence in the gas plant was a function of pH downstream of the water wash tower. As the pH increased in the absorber deethanizer, so did the hydrogen penetration rate. Control measure finally adopted to mitigate hydrogen blistering included recording of hydrogen probe pressures, pH of draw waters, analysis of wash water, and iron content of draw waters. Ferrocyanide spot tests were also made and inhibitors were tried. 8.4.2

Introduction

TIDEWATER Oil Company recently completed a 6-week shutdown of its fluid catalytic cracker and gas plant following a 19,000 hour run. Some interesting problems were encountered during this shutdown. During a run of this duration there was a noticeable build-up of corrosion scales. With long runs there also was less possibility of change of process and no change in process equipment during several periods of hydrogen attacks of gas plant equipment. Without these changes, investigation of the hydrogen blistering problem and the cause of recent attack was more easily accomplished.

Fluid Catalytic Cracking Unit Corrosion

Reactor Corrosion

The reactor was made from carbon-moly steel (A204 Gr. A Si killed) with a 7/64-inch-thick 10-14 chrome liner (A176 Gr. 2). The reactor shell varied in steel thickness from 13/16 inch at the top head to 1½ inch on the bottom head. The liner proved to be a source of trouble when repairs or alterations were necessary. The need for removing the liner about ½ inch from where a nozzle was to be installed, welding in the nozzle and then lacing over the area with 25-20 weld rod doubled the length and cost of what ordinarily would be a small job. This invariably provoked the question: is this alloy needed? Based on corrosion-erosion of carbon-steel parts of the reactor as noted below, it was felt that this liner was necessary to protect the vessel shell.

Figure 1 shows erosion on the diffusion grids at the bottom of the reactor. Coke formed in the openings or in the corner of the web and grew over some holes. As holes closed up more flow of oil vapor and catalyst was forced through the remaining openings thus accelerating the erosion. Scale is noticeable on the webs—particularly at edges where it had flaked off. This scale was in some cases as much as an eighth inch thick.

A qualitative analysis of the scale during the last shutdown proved it to be primarily iron sulfide. These grids, as pictured, had been cleaned off. Normally the scale was overlooked due to coke and the predominant feature of erosion. However, the loss of these grids was not due solely to erosion but was more properly a case of corrosion-erosion.

The top outlet of the reactor revealed the same corrosion-erosion. Figure 2 shows the inside of a carbon-steel cyclone. Parts of the eroded surface visible were of base metal with the scale being about ⅛ inch thick. The scale had the same grooved appearance as the metal itself and was usually most noticeable at edges where it spalled off. Coking was so prevalent that the scale was often hidden by the coke. An analysis of some chips of scale showed 78 percent iron, 22 percent sulfur.

In both of these cases erosion was more severe than the corrosion.

Reduction of the erosion lengthens the life of the equipment more satisfactorily than does using alloys to combat the mild corrosion. In the case of the reactor grids, the long length of run between shutdowns contributed to the loss of these grids. Since coke growth continues during the run once it is seeded, a one year run would not have allowed as many holes to be plugged. A shutdown would allow time to clean the grids and start with maximum open area the second year. This would reduce the erosion.

Lining the cyclones with hex-steel and wear cement extend their life. This can be continued as long as repairs can be made to the remaining metal. The corrosion reduces itself as long as the scale is left on the surface.

Replacement of these second stage cyclones (Figure 2) required longer hanger rods. The existing 11-13 chrome rods had 14 years service so could either be replaced or lengthened. Since the cyclones were on a rush order during this shutdown, any delay in installing them would extend the shutdown beyond the planned time. This necessitated evaluating extension of the existing rods rather than having new ones fabricated. Several publications[1,2] stated finding no appreciable change in high temperature strength or ductility of the medium chrome steels after prolonged exposure at elevated temperature under load.

Assuming that these hanger rods were still of sound material, lengthening was started. At this point weldability was given particular attention, but welding was accomplished without incident. The hanger rods were then to be reinstalled provided that the first rod finished could be proof tested.

The sample used was a 1⅝-inch cyclone hanger rod, with section welded in. The following procedure was followed:

1. Brinell hardness tests were made on the sample before and after stress relieving and after the elevated temperature load test.
2. The hanger rod was stress relieved at 1300-1450 F for 2 hours.
3. The sample was placed in the testing machine so that it was gripped at points approximately 9 inches from the

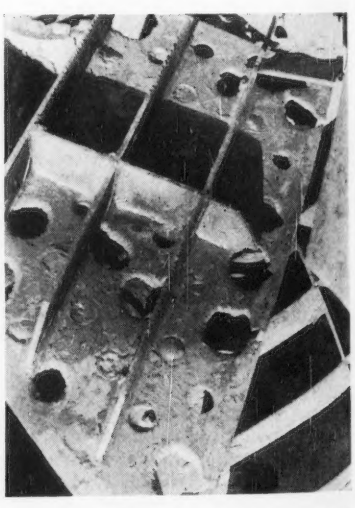

Figure 1—Corrosion-erosion of reactor diffusion grids viewed from underside.

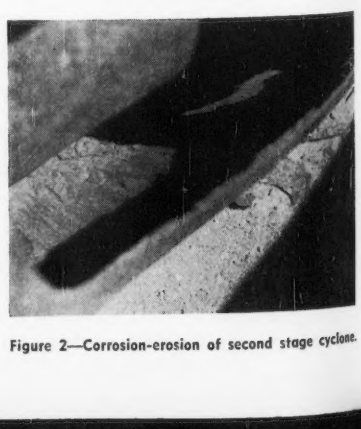

Figure 2—Corrosion-erosion of second stage cyclone.

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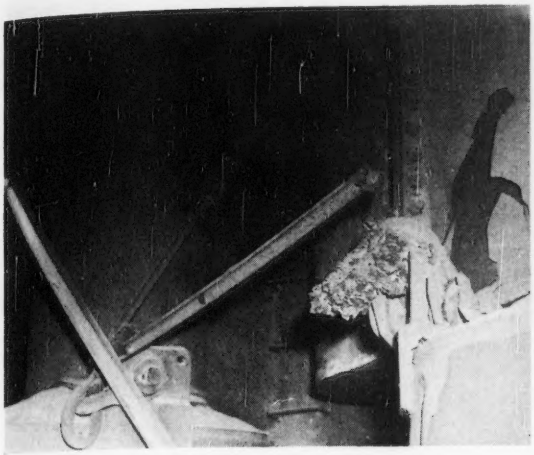

Figure 3—Burning of cyclone wall and corrosion of hanger rod.

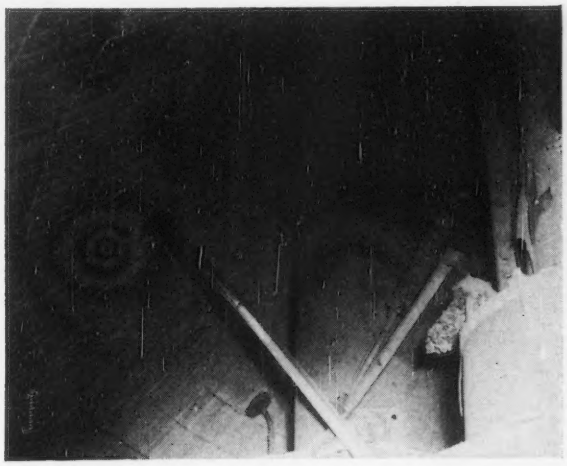

Figure 4—Corrosion of hanger rod and thermowell.

TABLE 1—Hanger Rod Test Results

Location	Brinell Hardness Number		
	As Received	After Stress Relief	After Load Test
1" to 2" from weld*	228	196	198
Weld	302	207	187
1" to 2" from weld	228	196	192
1" to 2" from weld	228	196	187
Weld	278	231	192
1" to 2" from weld	228	196	197

*Nearest the shackle end of the rod.
NOTE: No permanent elongation took place. With the exception of one crater crack, which probably was present before testing, no other cracks were discovered.

outer sides of the welds (ends of the added section). The portion of the rod between the grips was heated, as uniformly as possible, with a butane heating torch until a 1000 F Tempilstik melted when applied to the surface. A minimum temperature of 1000 F was held while a 7000 pound load was maintained on the sample for approximately 5 minutes.

4. The welds were checked for surface cracking using the Dy-Check method.

Table 1 gives the results. The load was arbitrarily set higher than service conditions but less than the yield stress. The hanger rod passed the test under simulated service conditions and all rods are now back in service.

Regenerator Corrosion

Corrosion in a regenerator is usually encountered in the form of oxidation from localized burning or from afterburning. Figure 3 shows a side of one regenerator cyclone subjected to localized burning. Although the iron oxide scale thickness is great, metal loss is usually slight. Therefore, this appears worse than it is. This oxidation is general throughout the regenerator which indicates oxidizing conditions. Figure 3 as well as Figure 4 shows a hanger or rod assembly with a large scale growth. The scale was swollen and granular appearing with a green and black surface. This same scale was on the thermowell extending through the dome in the bottom center of Figure 4.

This hanger rod had failed after 17½ weeks of service, but remained in the regenerator for the rest of the two-year run. This was one of six hanger rods that had been installed during the previous shutdown. With the rush of the previous shutdown, only one type of austenitic stainless was immediately available: Type 303, a machining grade containing sulfur or selenium. Thermowells were of Type 316 as a standard material for this service.

The scale from the hanger rod was analyzed in an effort to find out what happened to cause it to corrode so selectively. The analysis showed 44.3 percent nickel, 28.1 percent copper and 20.5 percent sulfur. The rest was 5.1 percent silica-alumina catalyst, 0.05 percent carbon, 1.95 percent unknown. The corroded part of the rod had been Monel. A magnet check on the remaining Monel immediately confirmed this. It was weakly magnetic, the Type 303 nonmagnetic. The oddity was not so much how Monel got there, as to how sulfide corrosion occurred in a location subject to afterburning from excess oxygen. However, since both copper sulfide and nickel sulfide are quite stable, the attack must have occurred during reducing conditions. The scale remained unaffected thereafter.

The remaining six hanger rods installed on the last shutdown were Type 303, just as shown in the records. Although this material was admittedly not the best for this service, it would be costly in time and money to change, even though replacement rods were already on hand. All hanger rods except these six were of Type 321. Previous experience had indicated that there was no creep in the Type 303.

The way the cyclones are supported shows that if two move in opposite directions from bed surges, impact may be the more important factor. Data published[1] on a test of many materials showed that Type 303 was slightly inferior to other grades of stainless for high temperature strength and impact properties, but far superior to the age embrittling straight chromes. Type 303 decreases in impact resistance with time as does Type 321 in other hanger rods. It was found that the aging occurred with or without stress. Impact properties of Type 303 after 19,000 hours at 1050 to 1200 F were obtained at room temperature and service temperature. Results were 46, 47 and 48 for an average of 47 ft. lbs. at 70 F and 33, 36 and 39 for an average of 36 ft. lbs. at about 1150 F. It was decided to keep the hanger rods in service for the next run.

Catalyst Lines

The riser sections of several catalyst lines were fabricated of Type 347. These have been in service for 14 years at temperatures exceeding 1000 F. The recycle risers started developing cracks during past shutdowns and particularly while any welding was being performed. A section of one was cut out adjacent to a cracked weld. Figure 5 shows the intergranular propagation from the weld into the parent metal.

The complete carbide precipitation evident prompted the analysis of the weld and parent metal shown in Table 2. Notice that although the columbium to carbon ratio exceeds the 10 to 1 minimum required in the parent metal, the columbium no longer stabilizes the carbides and prevents carbide precipitation. This intergranular attack started at the inside surface. This concurs with other reported experiences[3] that credit hydrolysis of sulfide scale by moisture as causing the intergranular corrosion. In spite of the carbide precipitation, cracks occurred only by the butt and seam welds of E309, not in the pipe wall itself.

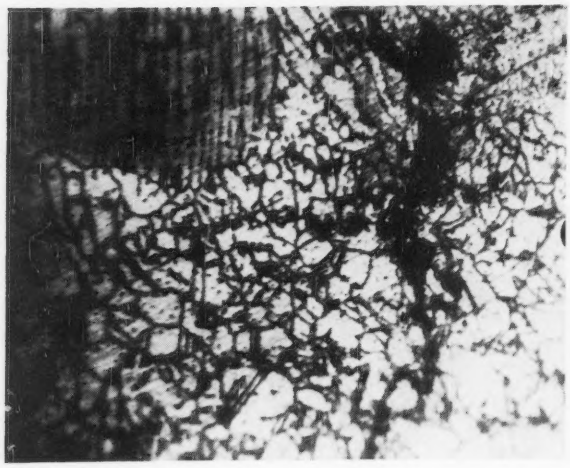

Figure 5—Weld (upper) and heat affected zone of Type 347 stainless steel. Intergranular corrosion extends into parent metal. Approximately 360X.

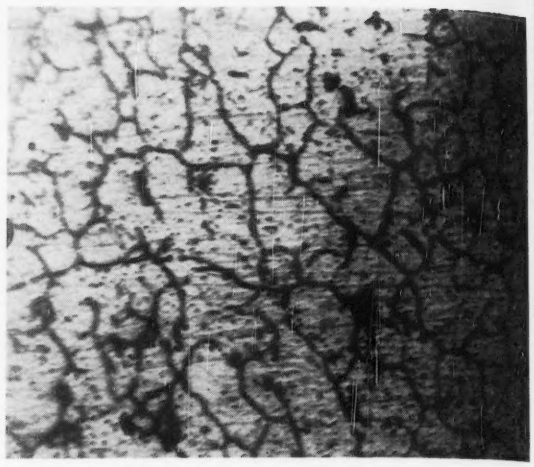

Figure 6—General structure of Type 347 stainless steel after 107,000 hours service at 950-1000 F.

The general structure of the Type 347 is shown in Figure 6. Etching was attempted to reveal any sigma phase. Although some spots may be suspected in this structure, they could not be selectively etched. Impact test results on the pipe wall material away from the weld were 45 ft. lbs. absorbed at room temperature. This is a general decrease from what would be normal for this metal, but still not brittle.

Three recycle lines of this material will be replaced during the next shutdown. Experience with another line of Type 347 (reactor riser) indicates that more and more cracking of the line will be evident on subsequent shutdowns. Once it has reached this stage it gets progressively worse. It took 11 years service before there was any cracking during shutdowns. Indications were that 16 years would be the maximum life expectancy.

FCCU Gas Plant

The main corrosion problem in the gas plant has been from hydrogen blistering. This blistering problem has been well covered by publications since 1949 that deal with the problem in catalytic cracker gas plants.

Tidewater's No. 4 Gas Plant

The No. 4 gas plant was built in 1943 with the 25,000 BPD fluid catalytic cracking unit. Design and operating changes have brought the catalytic cracker up to a 50,000 BPD rate. This has meant that the gas plant must keep pace. Major changes in equipment design have been made in recent years to bring the gas plant up to maximum throughput. Facilities to avoid hydrogen attack are now being expanded to match processing conditions.

Figure 7 shows an abbreviated flow diagram of No. 4 Gas Plant. Only the light ends section is included. Although hydrogen blistering has not occurred throughout this section, conditions have been present that could result in blistering. The water wash tower was installed originally to reduce corrodents and help prevent plugging of towers with salts. This tower serves to wash both the liquid pumped from the main accumulator and the wet gas stream after first stage compression. From the water wash tower both streams enter the absorber deethanizer. The bottoms from this tower then follow a normal fractionation.

Water washing has also been employed around the main accumulator. Recycling the water from the water wash tower to the accumulator has recently been employed to increase washing efficiency.

Evolution of Blistering Problem

In March, 1950, hydrogen blisters were first found in the compressor intake scrubber and lower intercooler. Until this time the water wash tower had successfully handled reduction of sulfides, cyanides, carbonates and phenols into the gas plant. Sprays were then installed in the fractionator overhead line under each condenser.

On the next two shutdowns, blisters were found in the intercoolers, the water wash tower, compressor intake scrubber, fractionator overhead condensers and on wet gas piping to the water wash tower. Therefore, on this second shutdown, a baffle system was installed in the main accumulator to allow washing of the gas stream as it passed through the accumulator. During this period hydrogen probes were being installed in areas subject to blistering.

During the next run through 1952 and early 1953 the water washing system was changed to allow water from the water wash tower to be used in the fractionator overhead sprays. This resulted in removal of about the same amount of contaminants. The advantages were a reduction in both water usage and amount of foul water. All the foul water could now be sent to the foul water stripper to reduce the water pollution problem.

The next change was to use stripped foul water instead of fresh water. Tests showed an increase in the amount of contaminants removed, particularly sulfides. The major disadvantage of using first recycled water and then stripped foul water was that at each step there was a reduction in the amount of phenols and cyanides plus thiocyanates removed. This allowed the more active promoters of hydrogen blistering to enter the gas plant.

TABLE 2—Chemical Analysis of Catalyst Line

SAMPLE	Parent Metal	Weld
Carbon (C)	0.08%	0.20%
Manganese (Mn)	1.21%	2.09%
Phosphorus (P)	0.02%	.....
Sulfur (S)	0.02%	.....
Silicon (Si)	0.40%	.....
Nickel (Ni)	10.05%	11.35%
Chromium (Cr)	17.10%	20.45%
Columbium (Cb)	0.93%	0.66%
Cb/c	11.6%	3.3%

Following the last change (using stripped water) there were no more blisters found between the water wash stages. This subdued any fears that the use of stripped water would promote hydrogen blistering. During the 1953 shutdown the present absorber deethanizer was installed, replacing a smaller tower that had never blistered.

In 1954 the absorber deethanizer was inspected and found blistered. The trays were primarily affected but a few blisters were on the shell. Water washing had controlled the hydrogen blistering to some extent but more so by dilution than by removal of contaminants.

First Step in Control of Blistering

The 1956 shutdown revealed a very slight increase in amount of blisters in the absorber deethanizer. All hydrogen probes were renewed and an inhibitor injection system was installed. The injection points noted in Figure 7 are at the fractionator, stripping still and depropanizer overhead lines, and the wet gas line ahead of the intercoolers and aftercoolers. On start-up, the draw waters were checked for iron and pH and the hydrogen probes were read. Injection was started with a filming amine inhibitor and some measure of control was established. Iron counts in excess of 1000 ppm were reduced to generally less than 50

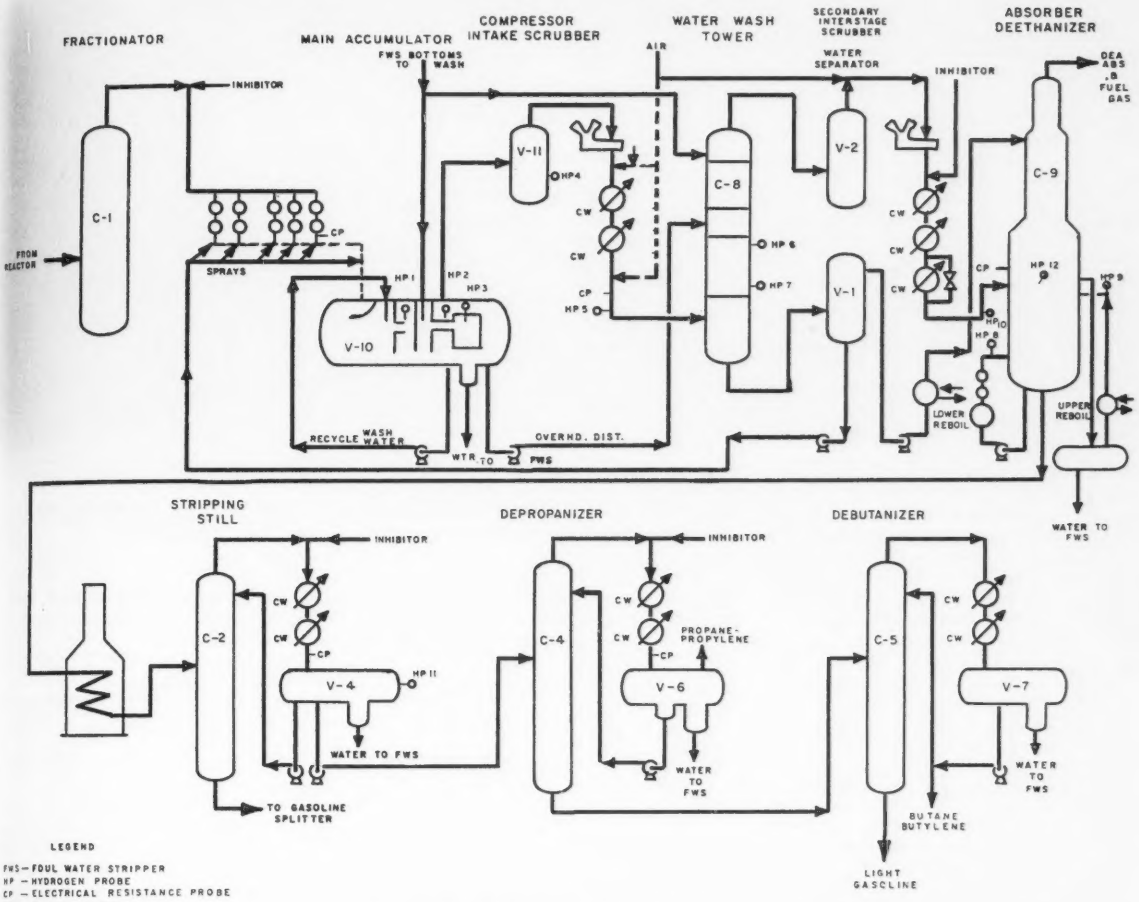

Figure 7—Partial flow diagram of No. 4 gas plant.

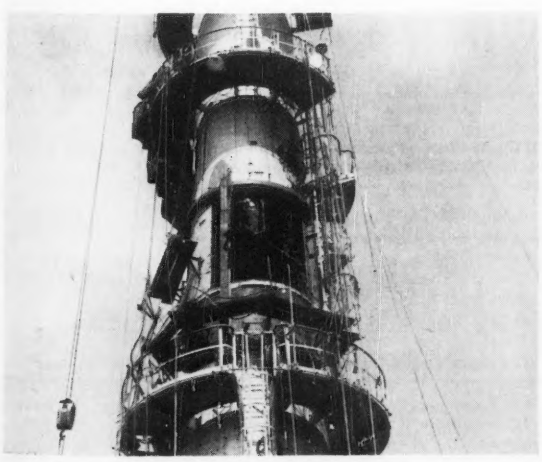

Figure 8—Removal of blistered plates from absorber deethanizer.

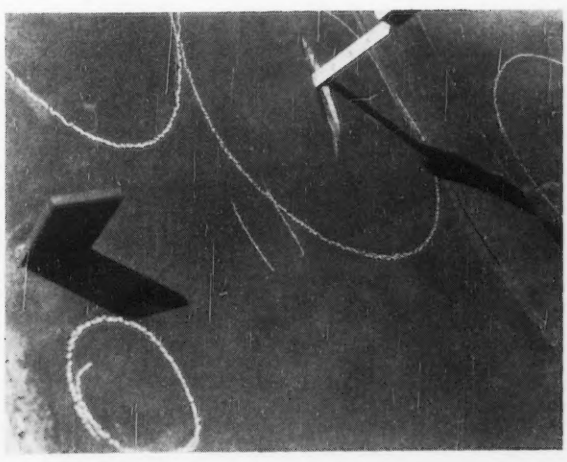

Figure 9—Crack ground open on internal blister. Blister wall was ½-inch and blister itself ½-inch.

ppm and most hydrogen probes stabilized themselves. The probe in the wet gas line was sporadically under control. The same could be said for some of the iron counts that soared occasionally but then appeared to be under control.

Through the latter part of 1956 and early 1957, vigilance was relaxed but inhibitor injection was continued. The most active hydrogen probe was on the wet gas line to the absorber deethanizer. This had stabilized itself in 1956 and in 1957, read 70 psig through April, May, June and the first part of July. On July 25, 1957, the first higher reading was recorded. The rate of increase from then on was about 9 psig per day. In September, 1957, blisters were first noticed on the outside of the absorber deethanizer. They were marked and a careful watch was kept through the rest of the run to insure no increase in blistering of the tower. Inhibitor rates were increased to 20 ppm on the wet gas line.

Latest Conditions

A number of plates in the lower section of the absorber deethanizer were damaged by blisters to such an extent that they had to be removed during the May, 1958 shutdown. Figure 8 shows removal of a shell ring in progress. Figure 9 shows one blister that had been ground out to calibrate the thickness. On 1⅛ inch plate the blister wall thickness was ½ inch and the blister gap about ½ inch.

Figure 10 shows sections of the shell ring removed from the tower. This was 1⅛ inch A212 Gr. B, one of the cleaner grades of steel. Notice that on the left of the seam weld there are numerous blisters, on the right, none. This pattern was followed on 3 shell rings affected by blistering. This pattern of dirty steel occurring at one end of the plate is common in structural grades and even affects weldability in these steels.

In silicon killed steels, such as this A212, this still seems to be true, though not severe enough to affect weldability. The one plate most affected by blistering had 0.17 percent silicon and 0.035 percent sulfur. The others in this area had 0.20 percent silicon and 0.030 percent sulfur. Both analyses are within limits of ASTM A212 Gr. B.

Figure 11 shows some of the larger internal blisters. These follow the usual pattern of cracking occurring in the direction of plate rolling. The lower part of the picture shows where a tray had been cut out.

Figure 12 shows two types of blisters found. The upper has two blisters. The smaller blister had cracked on its right edge and vented itself into the larger blister. The larger had cracked almost to the surface on the right edge. The lower plate has three fissures. The embrittled condition of the steel caused the left hand fissure to crack to the surface before yielding to form a larger blister.

All these blisters were found in the vapor space between the trays. Only two blisters were found where liquid was present. These were in a draw pan below the level of the nozzle. In all cases the concentration of corrodents would be unpredictable from draw waters because of localized concentrations in the draw pan and condensation on the vessel walls. The condensation on the vessel walls seemed to be eliminated in the lower part of the tower where external fireproofing kept the steel warm.

Downcomers required replacement in many trays throughout the blistered area because of uniform corrosion on the vapor side. Figure 13 shows a small piece of downcomer as viewed from inside the downcomer. The straight edge on the right is the overflow weir. The downcomers were fillet welded to the tray. The heat affected zone on 14 gauge material was also present on the opposite side of the thin sheet.

Localized attack of this heat affected zone can be seen including the start and end of the weld. The alkaline foul water present is known as one of the environments that can cause this type of corrosion.[4] Since the localized corrosion is only slightly more intense than the general corrosion, this is not a factor that is expected to decrease the life of the trays. Special heat treatment is therefore not worth considering.

Investigation of Hydrogen Probes Used

It was obvious that the hydrogen probes used were sensitive enough to indicate conditions that caused hydrogen blistering. However, one difference was noted between the probes used and the type described in the literature: The former did not have a lead filled tee. This was thought to have a great effect on the volume and subsequently the sensitivity.

Two types of probes were used in Tidewater's Avon Refinery. Both had a 0.365 inch OD reduced area 6 inches long but one used a 200 psig gauge with a 4½ inch dial. The other used a 200 psig gauge with a 2½ inch dial. The volumes of these probes were checked by filling with air to 14.7 psig and then measuring the volume of air released. The probe with the 4½ inch gauge dial had a volume of 16.7 ml and the probe with

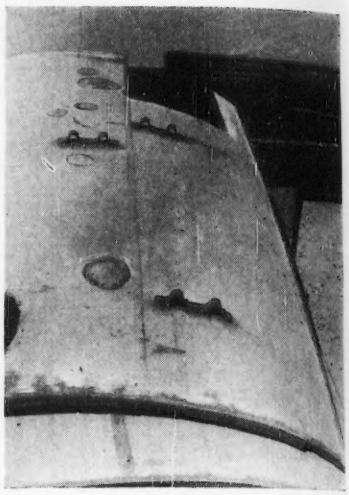

Figure 10—Vertical seam on absorber deethanizer plate. This shows blistering at one end of the plate, none at other.

TABLE 3—Comparison of Water Washing With Stripped Water or Industrial Water

USING 52 GPM STRIPPER WATER—MARCH, 1953

Property	Fresh Wash Water	Between-Stage Water From Water Wash Tower	Foul Water From Main Accumulator	Total Amount Removed
pH	9.8	8.5	8.9	.....
Sulfides	56 lb./day	3633 lb./day	10443 lb./day	10387 lb./day
Ammonia	876	3154	8229	7353
Carbonates	73	2352	4333	4260
Cyanides	6	13	18	12
Thiocyanates	10	10	34	24
Phenols	674	607	1531	857
Total Contaminants	1695	9769	24588	22893

USING 52 GPM INDUSTRIAL WATER—SEPTEMBER, 1952

pH	8.1	8.3	8.8	.....
Sulfides	0	2609 lb./day	7912 lb./day	7912 lb./day
Ammonia	0	1799	6138	6138
Carbonates	129	1346	3060	2931
Cyanides	0	63	88	88
Thiocyanates	0	11	26	26
Phenols	0	697	1932	1932
Total Contaminants	129	6525 lb./day	19156	19027

TABLE 4—Comparison of Wash Water Removal of Contaminants With Amount Entering Gas Plant (Also 170 GPM Wash Water to Sprays) Date 6/4/58

	Wash Water To C8	From C8	From Main Accumulator	Amount Removed
Rate	75 gpm	75 gpm	300 gpm	.....
pH	9.8	8.4	8.8	.....
Sulfides	43 lb./day	2800 lb./day	10823 lb./day	10740 lb./day
Cyanides + thiocyanates	72 lb./day	81 lb./day	262 lb./day	223 lb./day
Phenols	1570 lb./day	2260 lb./day	11820 lb./day	8830 lb./day

	Wet Gas To C9 Tower	Raw Distillate To C9 Tower	Total
pH water phase	10+	8+	.....
Sulfides	6910 lb./day	553 lb./day	7463 lb./day
Cyanides + thiocyanates	780 lb./day	547 lb./day	1327 lb./day
Phenols	181 lb./day	888 lb./day	1069 lb./day

TABLE 5—Wash Water Samples on 7/7/58 (60 GPM Wash Water to Sprays)

Property	Wash Water To C8	From C8	From Main Accumulator	Amount Removed
Rate	90 gpm	90 gpm	228 gpm	.....
pH	10.0	8.7	8.9	.....
Sulfides	0 lb./day	3030 lb./day	6570 lb./day	6570 lb./day
Cyanides + thiocyanates	433 lb./day	4 lb./day	328 lb./day	—394 lb./day
Phenols	583 lb./day	713 lb./day	2300 lb./day	1328 lb./day

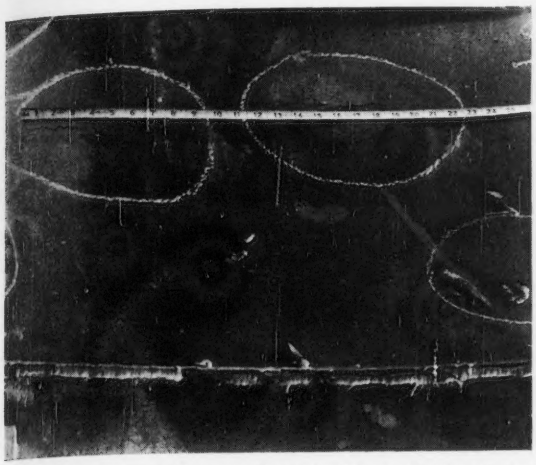

Figure 11—Large internal blisters cracked horizontally in direction of plate rolling.

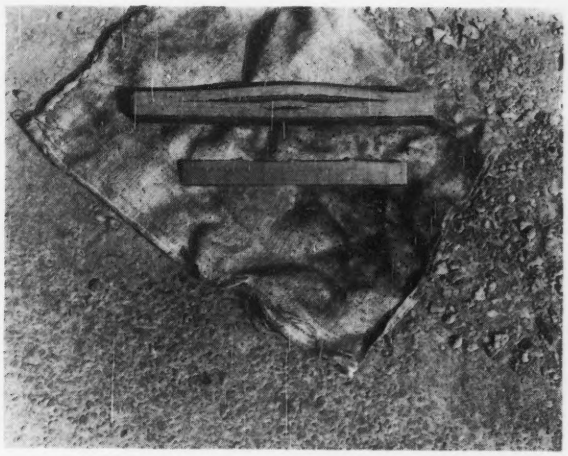

Figure 12—Blisters and fissures on 1¼-inch plate from absorber deethanizer.

the 2½ inch gauge dial a volume of 9.3 ml.

The required sensitivity was taken as 0.1 ml per square inch of hydrogen penetration. Skei, Wachter, Bonner and Burnham[5] reported that 0.1 ml per sq. inch per day does not lead to serious blistering.

In another paper Bonner and Burnham[6] reported that a hydrogen transmission rate of 0.1 ml per square inch per week (rather than per day) for 2 or 3 weeks was of little consequence. The probe with the 4½ inch dial pressure gauge therefore must be sensitive to about 1.5 psig increase in one week to meet the second condition. This is barely possible to read, and would definitely require several weeks to establish this trend.

As the pressure in the probe increases, the incremental pressure change is less at a given hydrogen transmission rate. Thus, for a probe that is zeroed and a rate of 0.1 ml per square inch per week the probe would be expected to read 1.5 psig the first week, 2.2 psig the second week and 5.4 psig in 7 weeks assuming 90 F temperature. Obviously these probes do not have the required sensitivity to detect what might be assumed as a safe hydrogen penetration rate. The higher safe rate of penetration of 0.1 ml per square inch per day suggested by Bonner and Burnham can barely be detected. Readings would be expected to be 1.5 psig in one day, 2.2 psig the second day and 5.4 psig after a week. Subdivisions on the 4½ inch pressure gauge are 2 psig.

The probe with the smaller pressure gauge has less volume but 10 psig subdivisions on the dial. It cannot detect 0.1 ml per sq. inch per week since that would require reading 2 psig in one week or 9 psig in 7 weeks. It is barely capable of detecting 0.1 ml/sq. inch/day.

None of the probes used are the retractable type since this investigation of the probes occurred just after start-up. Retractable type will now be installed where required and valves are available. Also reinforcing pads around vessel nozzles are being employed to give more sensitive results of hydrogen penetration rate.

Investigation of Water Wash

Table 3 shows a comparison of water wash using stripped foul water and industrial water. As mentioned before, more sulfides are removed but more phenols and cyanides plus thiocyanates are allowed to pass into the gas plant.

Table 4 shows the results of a test on the wash stream and the hydrocarbon streams from the water wash tower. The assumption that the samples of wet gas and raw distillate were representative was checked by the water content. The water content of the samples was about equivalent to the relative amount of water draw from the towers downstream. The water phase of the wet gas sample was 2400 ppm cyanide plus thiocyanate and it was 1200 ppm in the raw distillate. Results show that water washing is ineffective in removing cyanides to prevent hydrogen blistering.

A later test of the water wash only is shown in Table 5. Here again the lack of removal of cyanides plus thiocyanates is emphasized, particularly since this test shows them being stripped from the water. This proves that water washing is not effective in preventing hydrogen blistering because it does not remove the cyanides.

Normally, operating conditions of the catalytic cracker tie-in with the hydrogen probe activity. This has been true on some occasions, but exactly the opposite on other occasions. Water washing seems to hold the key to probe activity or lack of it. After a new foul water stripper was installed in June, 1956, a log of hydrogen sulfide and ammonia content in the wash water was kept. On each occasion that the probes were inactive the stripped water used for wash contained less than 10 ppm H_2S and 800 ppm NH_3. When the stripped water exceeded 40 ppm H_2S and 1000 ppm NH_3 as it did this July, the hydrogen probes immediately began to climb. Last year when probe activity started in July, the stripped water had changed suddenly from less than 10 ppm to over 100 ppm H_2S and from less than 400 ppm to over 2000 ppm NH_3. During the first week of probe activity the ammonia varied from 3600 to 4800 ppm. The probe on the wet gas line increased 9.6 psig per day (from 70 psig to 200 psig). This July the probe in the same location increased from 4 psig to 19 psig in 18 days. This is equivalent to 0.1 ml/sq. inch/day hydrogen penetration.

It is concluded that the stripped wash water used has held the key to the hydrogen penetration and resultant damage experienced at Avon Refinery. Contrary to past belief, pH of incoming wash water or foul water from the main accumulator is not an indication of pH in the rest of the gas plant. If, for instance, the concentration of both ammonia and H_2S increase in the same proportion, the pH will not change. If these higher concentrations make the incoming wash water almost saturated with the amount of ammonia it will absorb in the washing system, the ammonia formed in the cracking operations will not be absorbed and will pass into the gas plant. On the other hand, even a high H_2S content of 1000 ppm will allow the wash water to increase to the usual 3000 to 4000 ppm, thus reducing the amount of H_2S entering the gas plant. This results in an increase in pH throughout the gas plant since greater quantities of ammonia are left than are acid constituents. At higher pH, of course, the ammonium cyanide present causes the increased hydrogen penetration rates.

Controls Used During This Run

The ferrocyanide spot test has been used during the present run as a control measure. After start-up, faint blue lines were discernible but probe activity was absent. Electrical resistance probes had been installed in most of the locations that have hydrogen probes. These are noted in Figure 7 (the flow diagram) as "C.P." No change in reading has occurred since the start-up of the unit on June 1, 1958. Fluctuations up and down are noticeable on the probes in vapor service but these have been averaged out to the reading established a few days after start-up.

The hydrogen probe in the wet gas line to the absorber deethanizer showed

activity starting July 18, 1958. At the same time, the stripped water increased in sulfide content. Heavy blue lines appeared immediately when the ferrocyanide spot test was used. The spot test was continued and no change was noted for a month. Meanwhile air injection was started on July 25, 1958, ahead of the intercoolers in order to start the protection where blistering had occurred before. The rate was raised from .02 percent to .07 percent of wet gas flow in 6 days. Since the wash water recycles from the foul water stripper, air injection ahead of the intercoolers would allow less build-up of thiocyanates in the wash water than injecting in the fractionator overhead. The water wash tower was expected to provide good contact for both the wet gas and the raw distillate. This was effective enough to stop probe activity on August 4, 1958, 10 days later.

Cyanide spot tests were continued daily through this period and no significant change in the prussian blue lire or blue background on the spot was noted for 17 days. However, the red thiocyanate color was noted in the spot test on the day the probe activity stopped. Then the air injection point was moved from ahead of the water wash tower to the wet gas line between the tower and the second stage compressors. In 7 days the spot test showed a decrease in cyanides. By 5 more days the prussian blue color could hardly be found. Air rate was still about 0.07 percent of wet gas flow.

Control Downstream of Absorber Deethanizer

The stripping still (C-2), depropanizer (C-4) and debutanizer (C-5) all have some water draw from the overhead accumulators. Ferrocyanide spot tests on these waters had previously revealed that ferrocyanide concentrations were often higher than the absorber deethanizer foul water. As control was established on the absorber deethanizer, cyanide was removed from the system. The spot tests on draw waters from the other towers cleared up at the same time as the absorber deethanizer water.

Summary

Corrosion in fluid catalytic crackers is usually a minor problem. It becomes a factor primarily when coupled with erosion in cyclones or diffuser grids. Alloying is not usually justified except on stressed parts, such as cyclone hanger rods or the reactor shell. Material controls during fabrication are a problem for everyone, and the inadvertent use of Monel in the regenerator only reemphasizes the importance of maintaining controls.

Hydrogen blistering had developed into a major problem. Its recurrence for this gas plant is no doubt a function of pH downstream of the water wash tower. pH of the draw waters were not followed throughout the earlier runs since they were always constant when checked. This additional work load on the laboratory was dropped because it was not realized that the wash water from the foul water stripper would change enough to affect the pH through the rest of the gas plant. In retrospect, it is obvious now that wash water may stay constant at a pH of about 9.8, but its ability to absorb ammonia can be greatly reduced relative to its ability to absorb H_2S. This results in the important secondary effect of raising pH downstream. As the pH increases in the absorber deethanizer, so does the hydrogen penetration rate.

In a system such as this with so many operating variables that can cause hydrogen blistering, it never pays to assume that it is under control and requires no more attention. The present control system of recording hydrogen probe pressures, pH of draw waters, analysis of wash water, iron content of draw waters, and making ferrocyanide spot tests, will keep the hydrogen blistering problem under control.

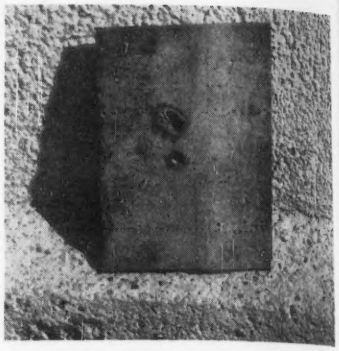

Figure 13—Localized corrosion at weld (opposite side of sheet) heat affected zone. Holes were burned through when cutting off the downcomer.

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Effect of Cold Drawing On Hydrogen Behavior in Steel*

By R. M. HUDSON and G. L. STRAGAND

Hudson

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Abstract

Hydrogen absorption by and the desorption rate of hydrogen from steel were studied as a function of cold work from 0 to 55.4 percent reduction using cold-drawn capped and killed SAE 1020 steel. Increased cold work increased the hydrogen solubility in these steels. Hydrogen desorption rate increased with increasing cold work until a maximum was reached at some point below 30.5 percent reduction. With further reduction, the desorption rate decreased. 3.7.3

Introduction

IT HAS BEEN established[1] that environmental conditions have a marked effect on the rate of hydrogen desorption from steel. Oxidizing agents actually hinder the desorption process, whereas immersion of steel in water at 38 C results in the highest desorption rate of hydrogen from steel for any of the environments studied. For environments containing appreciable moisture a second-order rate law applies, and for environments containing extremely low amounts of moisture a first-order rate law applies. The time required for hydrogen desorption from steel in a dry environment was significantly longer than the time required when steel was immersed in water. Öwe Berg[2] has suggested a sequence of surface reactions that may account for the catalytic effect of water on the desorption of hydrogen from steel. The fact that such large differences in hydrogen desorption rate exist shows that surface reactions are rate determining, and therefore, in continuing work on the influence of steel processing and other factors on hydrogen desorption from steel, the control of environment will be essential.

The present study, undertaken because of the practical importance of obtaining quantitative information on hydrogen behavior in steel, concerns the influence of cold work on the absorption rate of hydrogen into, the solubility level of hydrogen in, and the desorption rate of hydrogen from cold-drawn bars of capped and of killed SAE 1020 steel. Previously, it was shown,[3] by using low-carbon sheet-steel specimens having cold reductions up to 78.2 percent, that the hydrogen solubility in steel following acid pickling increased with increasing cold work and that a maximum value of hydrogen permeability and of desorption rate occurred at between 20 and 30 percent reduction. The present study was made to determine whether cold work introduced by cold drawing would affect hydrogen behavior in steel in a similar manner.

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Experimental

Materials

To study the effect of cold work on hydrogen behavior in steel, specimens of capped and of killed SAE 1020 were prepared representing reductions from 0 to 55.4 percent. The chemical composition of the two steels used is given in Table 1. As indicated in Table 2, hot-rolled bars of these steels were machined to various diameters between ⅝ and 15/16 inches, and these machined bars were then cold-drawn to reductions of 0, 17.2, 30.5, 40.8, 48.9 and 55.4 percent.

The 11/16-, ¾- and 13/16-inch-diameter bars were cold-drawn by single drafts. The ⅞-inch-diameter bars were cold-drawn in two drafts, each being ⅛ inch. The 15/16-inch-diameter bars were cold-drawn in three drafts, these being ⅛, 1/16 and ⅛ inch, in the order given.

Metallographic examination was made of both groups of cold-reduced samples by using a nital etch and a magnification of 250. Increasing amount of cold reduction increased grain distortion. As expected, the effect of cold reduction was markedly more pronounced in the longitudinal direction. For a given amount of cold reduction, the microstructure of the capped steel appeared to be similar to that of the killed steel. The microstructure of the bars was typical of carbon-steel bars having the compositions shown in Table 1. The pearlite was uniformly distributed. The ferrite grain size was consistently fine, with an ASTM grain size of 8.

For most of the work on hydrogen absorption during immersion in acid and for desorption rate studies, wafers of 3/64-inch thickness were cut from each of the ⅝-inch-diameter bars. For determination of hydrogen solubility levels in these steels it was necessary, for reasons discussed later, to use 1/32-inch-thick wafers. Individual specimens were vapor-degreased with trichloroethylene and stored in a desiccator until ready for use.

Reagent-grade sulfuric acid was used to prepare the acid solutions used for charging steel with hydrogen. Nitrogen gas containing less than 0.01 percent oxygen was used for deoxygenating water and for experiments in which desorption of hydrogen from steel held in a nitrogen atmosphere was studied. When dried nitrogen was required, the gas was passed through columns packed with solid desiccants and finally through a liquid nitrogen trap to remove moisture.

Apparatus and Procedure

Specimens to be charged with hydrogen were immersed in 2N sulfuric acid solutions at 38 C for various times. Hydrogen contents in charged-steel specimens and in specimens given treatments subsequent to charging were determined by the warm-extraction method described in an earlier publication.[4] Specimens were placed in specially constructed borosilicate-glass extractors and heated for 16 hours at 160 C under mercury. The hydrogen extracted from the steel by this method was collected over mercury and measured volumetrically.

TABLE 1—Chemical Composition of Steel Bars

Grade	Composition, Percent													
	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Al	Al_2O_3	N	As
SAE 1020, capped	0.27	0.57	0.009	0.040	0.012	0.025	0.035	0.038	0.025	0.00	0.002	0.001	0.004	0.008
SAE 1020, killed	0.20	0.50	0.006	0.022	0.19	0.025	0.016	0.034	0.011	0.00	0.027	0.003	0.006	0.007

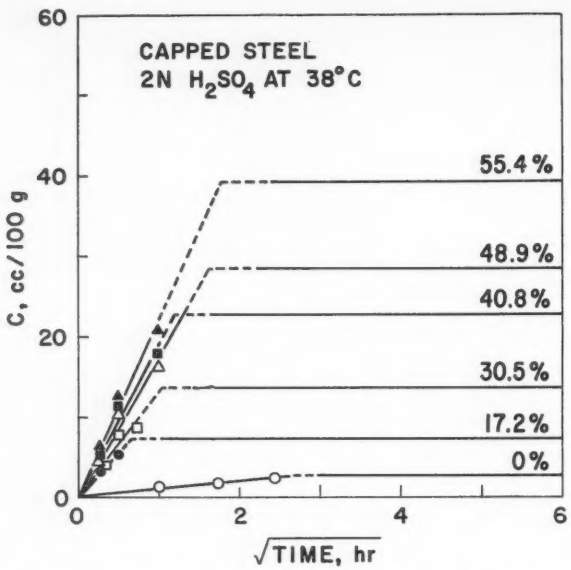

Figure 1—Hydrogen-absorption rate curves for capped steel as a function of cold work.

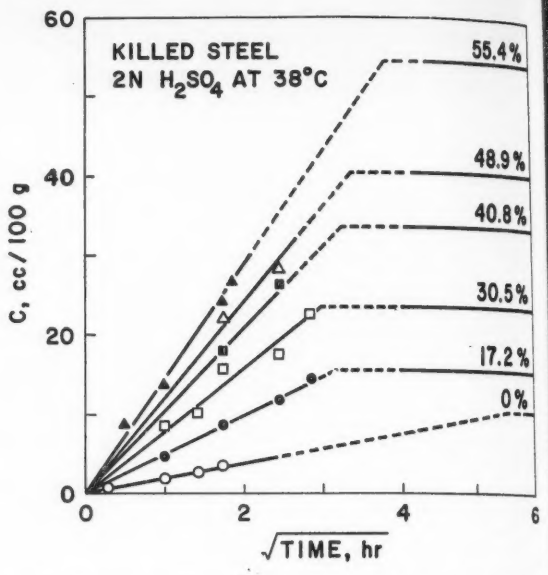

Figure 2—Hydrogen-absorption rate curves for killed steel as a function of cold work.

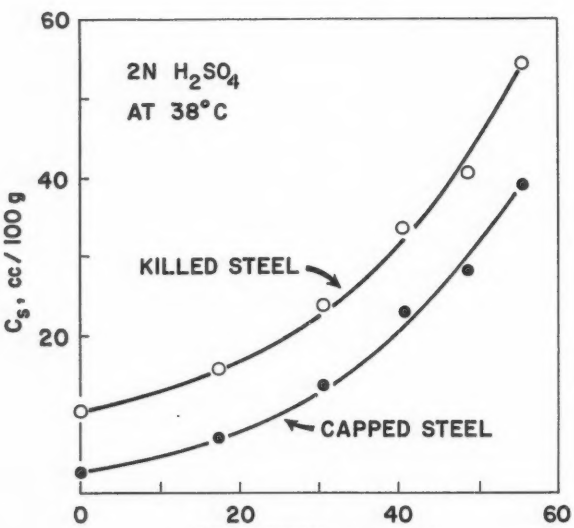

Figure 3—Hydrogen solubility as a function of degree of cold work.

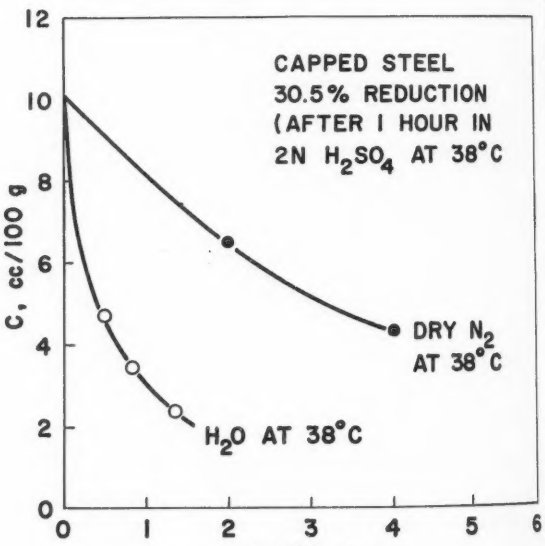

Figure 4—Hydrogen desorption rate as a function of environment.

Environmental Conditions

The usual procedure was to immerse steel specimens in 2N sulfuric acid at 38 C for a certain time. For a given steel, an attempt was made to make comparisons of hydrogen desorption rate between specimens having similar weight losses during the pickling; thus, though different initial amounts of hydrogen were introduced into the different specimens during pickling, the etching of the steel surfaces by pickling was probably similar. After charging, specimens were removed from the acid solution and thoroughly rinsed with running tap water for 15 seconds. Specimens were then given a final rinse with distilled water for 5 seconds prior to holding them for prescribed times under the various environmental conditions studied.

The rate of hydrogen desorption from steel specimens was studied in water and in dried nitrogen at 38 C. When the specimens were to be held in dried nitrogen, an additional drying treatment was used that consisted of rinsing the specimens with acetone followed by air drying. Not more than a minute was required for the operations that were performed subsequent to acid charging and prior to isolation in controlled environments.

Following storage under either deoxygenated water or dried nitrogen, all specimens were finally rinsed with distilled water for 5 seconds prior to determination of residual hydrogen content in the steel by the warm-extraction technique.

Results and Discussion

Influence of Cold Work on Hydrogen Absorption by Steel During Pickling

For both steels the change in hydrogen concentration with time of immersion

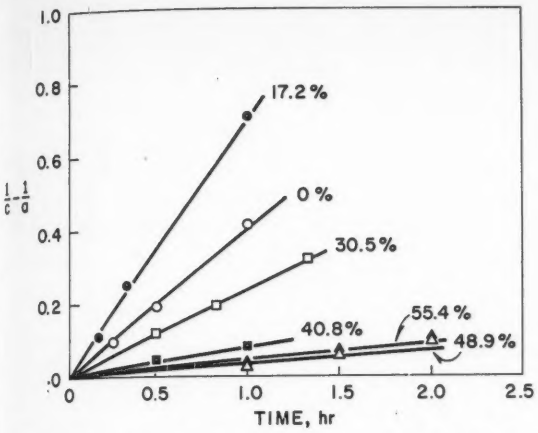

Figure 5—Hydrogen desorption from capped steel in water at 38 C as a function of cold work.

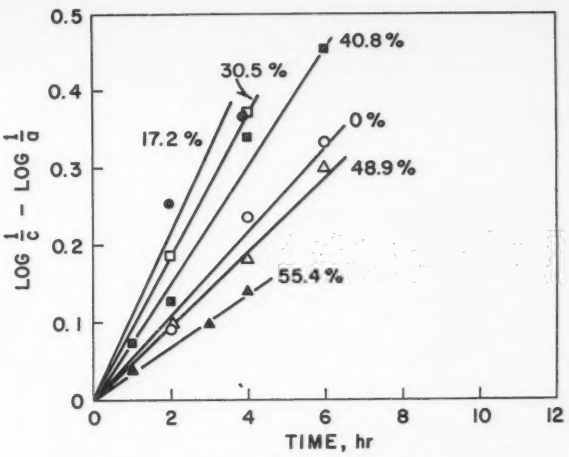

Figure 6—Hydrogen desorption from capped steel in dried nitrogen at 38 C as a function of cold work.

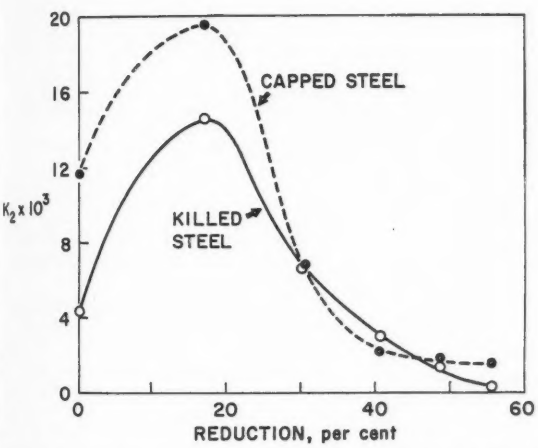

Figure 7—Hydrogen desorption rate in water at 38 C as a function of cold work.

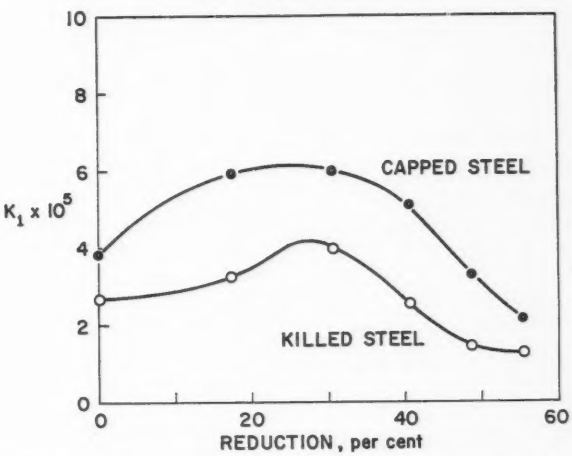

Figure 8—Hydrogen desorption rate in dry nitrogen at 38 C as a function of cold work.

in 2N sulfuric acid at 38 C was determined. The hydrogen-charging rate curves are shown in Figures 1 and 2. In agreement with the findings of Darken and Smith[5] and the authors' own recently reported work,[1, 3] the hydrogen concentration, C, increased linearly with the square root of the time the specimen was immersed in acid until a saturation concentration (hydrogen solubility) was attained. The points shown on Figures 1 and 2 were obtained on 3/64-inch-thick specimens. Because of the severe corrosion that these specimens are subjected to during extended periods of immersion in acid, it was necessary to determine hydrogen saturation concentrations by using thinner (1/32-inch-thick) wafers. As reported by Darken and Smith,[5] the time required to saturate steel with hydrogen is longer for thick specimens than for thin specimens.

Table 3 gives percentage weight losses for the 3/64-inch-thick specimens after 6 hours immersion in 2N sulfuric acid at 38 C. The increase in weight loss with increase in cold work demonstrates the marked effect of cold work on the pickling rate of steel. For specimens used in rate-of-removal studies, a 1-hour charging period was used so that the difference in weight loss between samples having different degrees of cold work would not be large.

TABLE 2—Cold-Drawing Schedule for Steel Bars

Initial Machined, Diameter, Inches	Initial Cross-Sectional Area, Sq. In	Final Cold-Drawn Diameter, Inches	Final Cross-Sectional Area, Sq. in.	Reduction, Percent
5/8	0.307	5/8	0.307	0.0
11/16	0.371	5/8	0.307	17.2
3/4	0.442	5/8	0.307	30.5
13/16	0.519	5/8	0.307	40.8
7/8	0.601	5/8	0.307	48.9
15/16	0.690	5/8	0.307	55.4

In Table 4 and in Figure 3 is shown the increase in hydrogen solubility, Cs, with increasing cold work that was observed for the capped and the killed steels. For a given degree of cold work, higher solubility levels were obtained for the killed steel.

From the slope of the hydrogen-absorption rate curve, λ; the hydrogen solubility, Cs; the density of the steel, ρ; and the thickness of the specimen, b, it is possible to compute the hydrogen permeability, P, of these specimens by using the equation

$$P = 1.25\rho\frac{\lambda^2 b^2}{Cs} \qquad (1)$$

derived by Darken and Smith.[5] Permeability is defined as the quantity of hydrogen (cc at STP) transferred in 1 second through a diaphragm 1 milli-

meter thick and 1 square centimeter in cross section.

By using the data obtained in the present study, hydrogen permeabilities were computed from the derived expression

$$P = 2.73 \times 10^{-7} \frac{\lambda^2 b^2}{Cs} \qquad (2)$$

where λ is in cubic centimeters per 100 grams per (hour)$^{1/2}$, Cs in cubic centimeters per 100 grams, b in millimeters, and the density of steel is taken as 7.8 grams per cubic centimeter. The steel thicknesses used in these computations were estimated from weight-loss data for one-half the time required to reach a hydrogen saturation level for each sample. Because of the severe corrosion occurring during pickling of these cold-worked samples, the permeability computed in this manner is probably subject to appreciable error. As shown in Table 5, for both steels there is evidence for a permeability maximum as a function of cold work. The permeabilities for the capped steel were greater than those for the killed steel. These results are similar to those of Schumann and Erdmann-Jesnitzer,[6] who reported that the rate of passage of electrolytically charged hydrogen through low-carbon sheet-steel diaphragms increased with increasing cold work up to 10 to 20 percent reduction and that this rate decreased rapidly with further cold work.

TABLE 3—Pickling of Steel in 2N H_2SO_4 at 38 C as a Function of Cold Work

Reduction, Percent	Weight Loss After 6 Hours, Percent	
	Capped Steel	Killed Steel
0.0	11.7	21.5
17.2	18.3	28.2
30.5	23.5	35.6
40.8	29.5	43.0
48.9	30.4	50.0
55.4	42.0	53.7

TABLE 4—Hydrogen Solubility in Steel Immersed in 2N H_2SO_4 at 38 C as a Function of Cold Work

Reduction, Percent	Hydrogen Solubility, cc/100 g	
	Capped Steel	Killed Steel
0.0	2.8	10.5
17.2	7.1	15.6
30.5	13.6	23.5
40.8	22.9	33.6
48.9	28.2	40.4
55.4	39.1	54.5

TABLE 5—Hydrogen Permeability* Estimates From Hydrogen-Absorption-Rate Data

Steel	Reduction, Percent	λ, cc/100 g/hr$^{1/2}$	Cs, cc/100 g	b, mm	$P = 0.273 \times 10^{-6} \frac{\lambda^2 b^2}{Cs}$
Capped	0.0	1.0	2.8	1.11	0.12×10^{-6}
	17.2	11.5	7.1	1.19	7.2×10^{-6}
	30.5	13.3	13.6	1.18	5.0×10^{-6}
	40.8	19.1	22.9	1.16	5.8×10^{-6}
	48.9	17.7	28.2	1.13	3.9×10^{-6}
	55.4	22.3	39.1	1.08	4.0×10^{-6}
Killed	0.0	1.9	10.5	0.48	0.22×10^{-7}
	17.2	5.0	15.6	0.88	3.4×10^{-7}
	30.5	8.0	23.5	0.88	5.8×10^{-7}
	40.8	10.5	33.6	0.77	5.3×10^{-7}
	48.9	12.1	40.4	0.64	1.1×10^{-7}
	55.4	14.4	54.5	0.40	1.7×10^{-7}

* Unit for permeability is cm^2/sec.

Effect of Degree of Cold Work on Rate of Hydrogen Desorption From Steel

For studies on the rate of hydrogen desorption, specimens of each sample were given an initial hydrogen charging by immersion in 2N sulfuric acid at 38 C for 1 hour. The desorption rate was determined for steel specimens immersed in water at 38 C and for steel specimens stored in dried nitrogen at 38 C. The desorption of hydrogen from steel was much more rapid in water than in dried nitrogen, as illustrated in Figure 4. This difference, reported in previous work,[1] is evidence for the importance of steel surface reactions in the desorption of hydrogen from steel.

The desorption rate in water, k_2, followed a second-order law, and the rate in dried nitrogen, k_1, followed a first-order law, as illustrated by the linear plots obtained — $(1/C - 1/a)$ vs t for water, and $(\log 1/C - \log 1/a)$ vs t for dried nitrogen — for the capped steel. In this connection note Figures 5 and 6, where a is the concentration of hydrogen in steel for time $t = O$, and C is the residual hydrogen concentration in steel at time t. For both environmental conditions studied, it was determined that with increasing cold work the desorption rate increased to a maximum and that further increase in cold work beyond this point resulted in a decrease in desorption rate, Table 6 and Figures 7 and 8.

For SAE 1020 steel, capped and killed grades, the hydrogen solubility in the metal as introduced by acid pickling increases with increasing cold work, but the rate at which hydrogen so introduced into the steel can be subsequently desorbed is less for severely cold-worked materials.

Summary

The present work confirms earlier results[1] showing the importance of surface reactions in the desorption of hydrogen from steel. The hydrogen solubility in steel following acid pickling increases with increasing cold work. A maximum value of hydrogen permeability (calculated from charging-rate data according to the method of Darken and Smith) and of desorption rate in water and in dried nitrogen at 38 C as a function of cold work was observed. Severely cold-worked steel displayed a considerably lower desorption rate than less severely cold-worked steel.

Acknowledgment

The authors wish to express their gratitude to E. E. Bishop of the Wyckoff Steel Co., Ambridge, Pa., for his cooperation in cold drawing the hot-rolled bars used for this investigation.

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DISCUSSION

Comments by T. G. Owe Berg, Douglas Aircraft, Inc., Long Beach, California:

This note is offered in order to call due attention to the comparison between killed and capped steels. This comparison is of particular interest since the data were obtained under well defined conditions. The difference between the two steels is therefore real and not one between two sets of experimental conditions. The paper supplies a valuable confirmation of the results of Erdmann-Jesnitzer and Sabath,[1] who studied the effects of Si additions up to 4 percent upon the rates of desorption and permeation.

It was pointed out in a recent paper[2] that cold work and other metallurgical factors affect hydrogen exchange with metals by affecting the "retained" hy-

TABLE 6—Rate of Hydrogen Desorption From Steel As a Function of Cold Work

Steel	Reduction, Percent	After 1-Hour Pickle in 2N H_2SO_4 at 38 C		Hydrogen Desorption Rate*	
		Weight Loss, Percent	Hydrogen Concentration, cc/100 g	Water at 38 C, $k_2 \times 10^3$	Dry N_2 at 38 C, $k_1 \times 10^3$
Capped	0.0	1.8	1.2	11.8	3.8
	17.2	2.0	5.1	19.6	5.9
	30.5	2.3	10.1	6.8	6.0
	40.8	3.2	17.9	2.3	5.1
	48.9	3.2	16.2	1.8	3.3
	55.4	3.8	20.9	1.6	2.1
Killed	0.0	1.5	1.9	4.2	2.7
	17.2	1.8	4.6	14.6	3.3
	30.5	2.6	8.5	6.7	4.0
	40.8	2.5	12.9	3.0	2.5
	48.9	3.4	13.9	1.4	1.4
	55.4	4.6	20.1	0.4	1.2

* Unit for k_2 is g/cc (STP)/sec.
Unit for k_1 is reciprocal seconds.

drogen, whereas the hydrogen held in solid solution is affected by surface conditions alone. The retained hydrogen is held in a precipitate, the most important precipitate being ε-carbide, although other hydrogen-rich precipitates may also be important in special cases, (e.g., ε-nitride and TiN.) In particular, cold work increases the apparent solubility of hydrogen in steel by increasing the amount of ε-carbide in the steel. The effect of Si upon ε-carbide has been studied by Pomey et al[3-5]: Si stabilizes ε-carbide. Consequently, it should increase the apparent solubility of hydrogen in cold worked steel. By the same token, Si should retard desorption of this retained hydrogen. Other alloying elements which stabilize ε-carbide, (eg., Cr[6]), also reduce the rate of hydrogen desorption and permeation[7].

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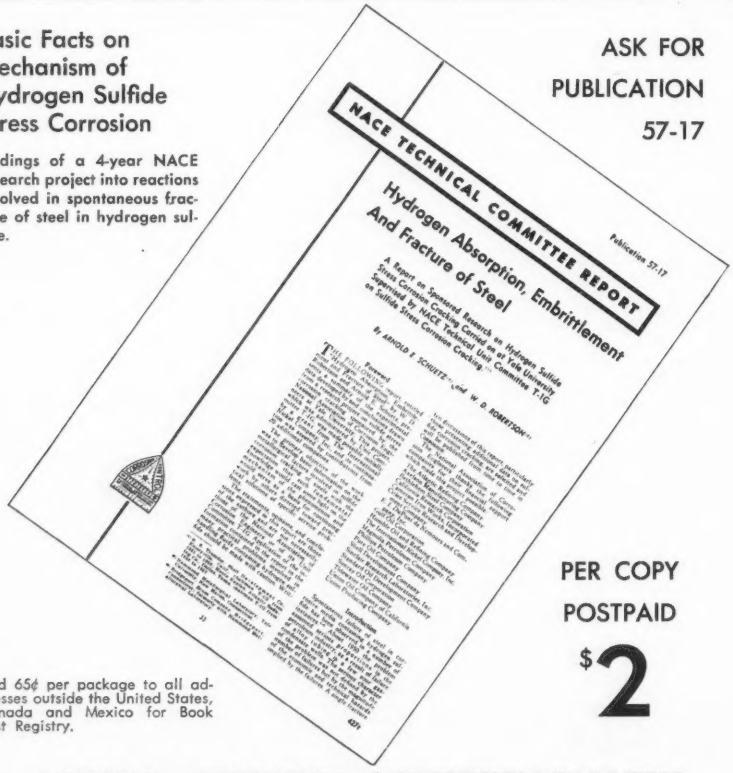

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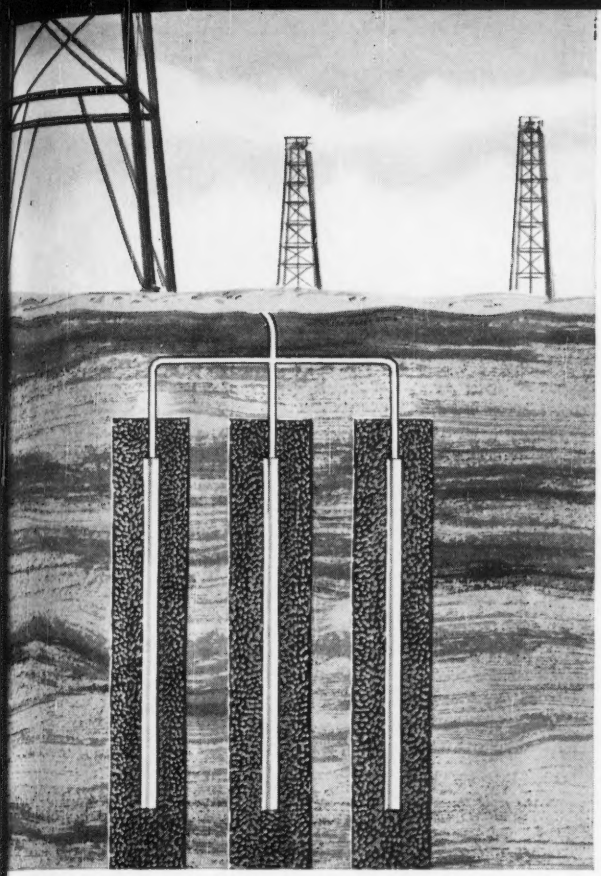

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"Squeezing" a well with Corban involves the pumping of inhibitor through the tubing string into the producing formation. The tubing and other metal parts contacted by the Corban, receive a protective film of inhibitor. As the well is produced, Corban from the formation maintains this protective film for an extended period.

The inhibitor squeeze method was first used to combat corrosion in Louisiana and East Texas wells which were difficult to treat conventionally.

One of the first wells squeezed with Corban was a gas distillate well on the Louisiana Gulf Coast in June of 1956. Since then, this well has been squeezed with Corban four times. A recent caliper survey was compared with one made prior to the first squeeze. The comparison showed that no noticeable corrosion had occurred during that three-year period. No down-hole equipment had been replaced on this well during this time. Other wells in this area, treated with different methods, had required some replacement of tubing due to corrosion.

Get an engineered recommendation on the use of Corban in your wells from your nearest Dowell office or station. Or write Dowell, Tulsa 1, Oklahoma.

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